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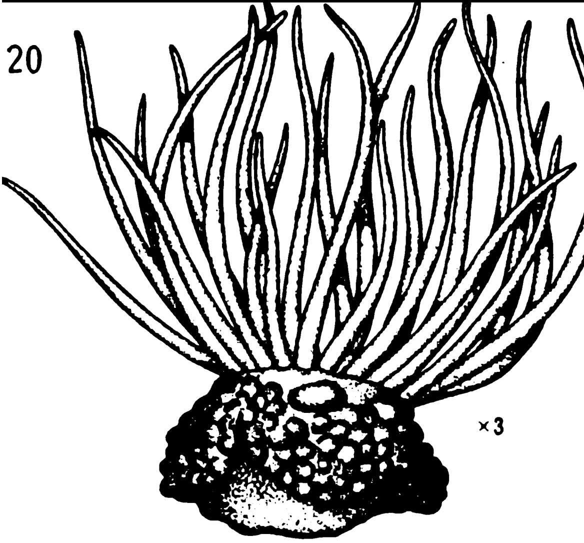

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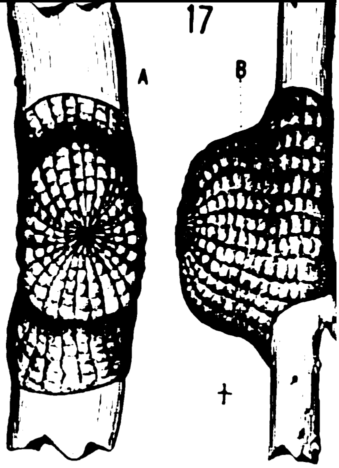

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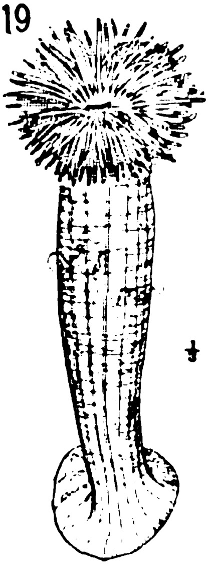

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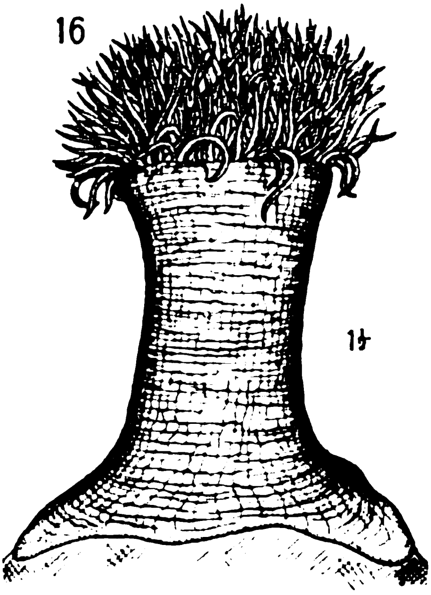

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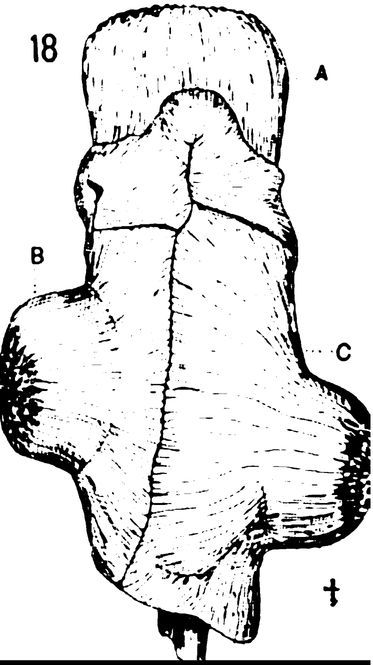

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Thermodynamic Relations of Hydrated Glass*;[*]

by C. BARUS.

1. FURTHER treatment of the fusible water-glass described in the preceding communication[†] has brought out the following points: During the first or opaque stage of the reaction of hot water on glass (200°), volume-contraction $(\frac{v}{V})$ and increase of compressibility (β) are both marked phenomena. During the second stage the water-glass becomes more and more clear and limpid. Volume-contraction falls off asymptotically to zero. Compressibility, after passing through a pronounced maximum which may be even larger than $500/10^6$ per atmosphere, diminishes with great rapidity to the probable isothermal value for pure water (about $100/10^6$). The relation of change of compressibility to the corresponding volume-contraction (per unit of volume, cold), i, e. $\delta\beta/(\delta v/v_0)$, remains throughout of nearly the same order, lying within an interval of $10/10^6$ to $20/10^6$, and nearer the former limit so far as measurable. The total apparent volume-contraction of the hot column of water-glass may reach 30 per cent.

2. On cooling *bubbles* appear in the clear water-glass in great number, showing it to contract on solidifying from the center outward (centrifugally), like a Prince Rupert drop. The solid water-glass is in appearance as hard and brittle as ordinary glass,

---

[*] Read before the Nat. Academy of Sciences, Nov. 16th, 1898.

[†] This Journal (4), vi, p. 270, 1898; cf. this Journal (3), xli, p. 110, 1891. The experiments of this paper ending with compressibilities as high as $200/10^6$, relate chiefly to the opaque stage.

from which it differs in refraction and density. Capillary tubes at the end of the process have become glass rods. The original thread of water is replaced by a solid core of water-glass more than twice the original diameter.[*]

Nevertheless all capillary tubes with a solid core of this kind *break* throughout their length in the lapse of time, however carefully cooled. Cf. § 5.

3. An explanation of these phenomena may be given in the terms of the compressibility observed along the successive isotherms for the different concentrations of glass solution at 210°. This at first shows a relatively small value, implying a steep isotherm in a Clapeyron (pv) diagram. Thereafter compressibility passes through a relatively enormous value (over 5 times the initial result), implying a nearly horizontal isotherm. The reaction ends with even smaller compressibility than the first observed, implying steeper isotherms than the initial curves. Now although these isotherms are all at the same absolute temperature, the water-glass is becoming continually more concentrated and viscous. Hence the *corresponding temperatures* of the isotherms in van der Waals' sense are continually decreasing. It follows that the reaction considered as a thermodynamic process is a march through the *critical region* of certain phases of the water-glass examined.

4. In the light given by J. W. Gibbs's famous investigations, one may arrive at clear notions by adopting but two phases of the water-glass, for comparison. Many phases may coexist; two are selected in the interest of brevity and called phase 1 and 2, respectively. During the earlier stages of the reaction (dilute water-glass) phase 1 is stable. At the end of the reaction (concentrated water-glass, subsidence of volume contraction) phase 2 is stable. Both cases correspond to steep isotherms. Toward the middle region of the reaction (maxima of compressibility) phases 1 and 2 are mutually stable in presence of each other. Hence the horizontal isotherms corresponding to the critical region are cut through in a march from greater to smaller corresponding temperatures.

That phase 2 is really unstable during the first stage of reaction is shown by the approximate constancy of the values of compressibility, throughout intervals of pressure as high as could be applied. For instance, at 185°,

Interval, $p =$	20–100	100–200	200–300	300–400 atm.
$10^6 \times \beta =$	146	144	142	146

And fifteen minutes later

$10^6 \times \beta =$	188	176	201	189.

---

[*] Diameters of threads of water and of water-glass respectively in tube No. 4, ·024 and ·071^{cm}; in tube No. 5, ·033 and ·059^{cm}; in tube No. 6, ·053 and ·125^{cm}; etc.

Again, during the intermediate stage, water-glass is non-resilient: yielding remarkably to increase of pressure, it refuses to expand when pressure is removed. The last stage is again elastic but relatively incompressible.

The extreme compressibility of water-glass during the stated intermediate stage deserves especial comment. Beginning with igneous glass and water* with compressibilities of the order of $3/10^6$ and $100/10^6$ respectively at 210°, values are reached in water-glass which exceed $500/10^6$. One may even compare this result with so volatile a body as ether at different temperatures and between 100 and 200 atm., as follows:

Temperature =	29°	65°	100°	185°
$\beta \times 10^6$ =	156	207	305	741

Yet the water-glass solidifies in the cold to a hard colorless body quite resembling igneous glass.

5. Made in quantities in a large digester, water-glass is obtained as a nearly homogeneous compact body, adhering forcibly to the walls of the retort, from which it must be removed with wedge and hammer. A small lump held above a candle flame soon fuses with loss of water to a milk-white pumice. Left without interference in the cold for several weeks or months, it spontaneously cracks and crumbles, eventually becoming a loose mass breakable in the fingers, while the original lump could be broken only with a hammer. In the cold, therefore, phase 2 is unstable and passes back spontaneously into phase 1. Water is set free, probably under great pressure, and hence the gradual crumbling of the mass. When compared with the disintegration of minerals, we have here an example of an enormously rapid chemical reaction, in solids. The breakage of capillary tubes in the lapse of time instanced above, § 2, is thus explained.

---

*The rapidity with which water attacks glass vessels at 210° makes it impossible to obtain more than an estimate of its compressibility. See my earlier paper.

Brown University, Providence, R. I.

Art. II.—*Platinum and Iridium in Meteoric Iron;* by JOHN M. DAVISON.

[Read before the Rochester Academy of Science on October 11, 1898.]

SOME time ago a color reaction, given by potassium iodide with a residue from a solution of Coahuila meteoric iron, led me to suspect the presence of platinum. To test the matter, three attempts were made to separate this element from meteoric iron; the first with 108·6 grams of the Coahuila iron; the second with 500 grams of the same iron; the third with 464 grams of the Toluca iron. The hydrochloric acid solution of these irons left a fine black sediment consisting mainly of minute, tetragonal, prisms of rhabdite; minute, black, irregular crystals, which may also be rhabdite; carbon, and a little stony matter.

From this sediment platinum was obtained in each analysis. There was got from the 608·6 gms. of Coahuila iron 0·014 gms. of metallic platinum, and 0·0015 gms. of a black powder, insoluble in nitro-hydrochloric acid, but, after fusion with zinc, dissolving in that acid and giving with ammonium chloride a dark-red crystalline precipitate, which is probably ammonium iridi-chloride.

From the 464 gms. of Toluca iron a few crystals of potassium platinichloride were obtained. These show a reddish color, and probably contain iridium. The hydrochloric acid treatment of 500 gms. of Coahuila iron left 9·386 gms. of residue: that of the 464 gms. of Toluca iron left 0·944 gms. of residue, which contained more stony matter than did that from the Coahuila. This stony matter was much decomposed by the acid.

Careful search was made for microscopic diamonds. None were found in either meteorite. The few transparent grains, left with the carbon after all soluble matter had been removed, were decomposed by hydrofluoric acid.

From these analyses all platinum utensils were, of course, carefully excluded, the reagents tested, and all precautions taken against accidental contamination.

ART. III.—*Studies in the Cyperaceæ;* by THEO. HOLM. VIII. On the anatomy of some North American species of *Scleria*. With figures in the text, drawn by author.

HAVING discussed the composition of the inflorescence in a previous article,* let us pass to examine the anatomical structure of some of our native species: *S. pauciflora* Muhl., *S. triglomerata* Michx., *S. oligantha* Michx., *S. Baldwini* Steud., *S. ciliata* Michx., *S. filiformis* Swtz., *S. Elliottii* Chapm., *S. Torreyana* Walp., *S. reticularis* Michx., *S. hirtella* Swtz. and *S. verticillata* Muhl.

The root.

All our species are perennial and the roots are generally very strong and develop especially from the lower side of the rhizome; they possess much the same structure as has been described before as characteristic of roots of other genera of this large order, but differ from these, however, by the development of the innermost three or four layers of the bark-parenchyma into a sheath of very thick-walled cells, which surrounds the endodermis. This sheath, in connection with the very thick-walled endodermis, forms a very strong mechanical support to the central-cylinder. Otherwise the root shows an epidermis of usual structure, a hypoderm and an outer bark with large lacunes from the tangential collapsing of the cells, in contrast to the inner layers (B in fig. 1), which, as described above, forms a very solid tissue.

The endodermis represents a typical O-endodermis, and surrounds a pericambium of normal structure. There are several large vessels in alternation with groups of leptome, and the innermost part of the central cylinder is occupied by a large mass of thick-walled conjunctive tissue.

This structure of the root was observed in species from various localities; from low, swampy ground and from dry, sandy soil in High Pine woods of subtropical Florida.

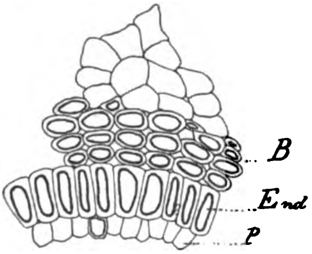

FIG. 1. Root of *S. pauciflora;* transverse section. B, inner bark; End., endodermis; P, pericambium. ×400.

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* This Journal, vol. v, January, 1898, p. 47.

The rhizome.

While the ramification of the stem underground is sympodial in our species, we may, nevertheless, distinguish three forms or modes of growth, viz: cespitose, creeping and tuberous. The first of these is exhibited by *S. verticillata*, and partly, also, by *S. reticularis* and *S. Torreyana*, and does not differ from the usual cespitose rhizomes of other Cyperaceæ. *S. ciliata* and *S. hirtella* have creeping rhizomes reminding one of *Fuirena scirpoidea*, which we have described in a previous paper.* The third form, the tuberous, is well exemplified by *S. pauciflora* and partly, also, by *S. filiformis* and *S. Elliottii*. In these species we notice that the rhizome is very much branched with relatively short internodes, densely covered by rudimentary sheathing leaves. The two basal internodes of each flower-bearing shoot are, furthermore, distinctly swollen so as to give the whole rhizome a peculiar knotted appearance. It is the basal internodes of the axis of first order that show such swelling, while the secondary axis grows out as a short, creeping and rather slender branch.

The development of these forms of rhizomes does not seem to depend upon the character of the soil, since the creeping is noticed in damp (*S. hirtella*) as well as in very dry sandy soil (*S. ciliata*). The cespitose form is especially characteristic of *S. verticillata*, which was collected in damp soil, like *S. reticularis* and *S. Torreyana*. The third form is common to species from dry, sandy to rich or swampy ground. Examining the internal structure of the rhizome of *S. pauciflora*, we notice a thick-walled hypoderm of about three layers inside the epidermis, and bordering on a large bark-parenchyma of thin-walled cells, which contain deposits of starch. The endodermis is not very well differentiated, but seems to consist of rather irregular, thick-walled cells. The innermost part of the rhizome consists of a large, starch-bearing fundamental tissue in which a number of collateral and perihadromatic mestome-bundles are imbedded, each of which is surrounded by layers of stereome. A corresponding structure is, also, noticeable in the tuberous base of the stems, but in these we observed a distinct and thin-walled endodermis, and noticed that the stereome around the mestome-bundles is only weakly developed.

In *S. ciliata* and *S. hirtella* we find a similar structure, but the cells of endodermis are more thin-walled. The stereome when compared with that of *S. pauciflora* is much heavier in *S. hirtella*, and much weaker in *S. ciliata*. Reservoirs of tannin were observed in all three species, and seemed to be especially abundant in the bark and fundamental tissue of *S. ciliata*.

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*This Journal, vol. iv, July, 1897, p. 25.

The aerial stem

which bears the inflorescence is sharply triangular in our species, glabrous or sometimes covered with a few, unicellular hairs along the upper part of the edges, and these are sharply pointed and directed upwards. As in most of the other *Cyperaceæ* with sympodial shoots, the flower-bearing stem is in *Scleria* preceded by a few leaves, which winter over.

In its anatomical structure the stem of *S. pauciflora* shows a distinct cuticle and an epidermis with very thick outer walls. The characteristic siliceous cones which we have mentioned in our previous papers are, also, noticeable in this genus, in those cells of epidermis which lie over the stereome. The bark-parenchyma contains chlorophyll and consists of a compact tissue with several tannin-reservoirs scattered here and there. It is interrupted by the stereome, which covers the leptome-side of the mestome-bundles, reaching through the bark outwards to the epidermis. Viewed in transverse section, the stereome is seen to form a large group between the sides of each of the three angles of the stem, while the angle itself is occupied by bark-parenchyma. The mestome-bundles are arranged in two alternating bands, the outer consisting of large and small ones, the inner only of large ones completely imbedded in the pith, which is solid in this species. A like structure occurs in the lateral peduncles, which, however, are covered by hairs of the same shape which we have described as characteristic of the main stem.

The structure of the angle of the main stem seems to offer very good anatomical characters for the species of *Scleria*, and the following differences have been noticed. In *S. pauciflora* the angle is occupied by bark-parenchyma, which partly surrounds a very small mestome-bundle with little or no support of mechanical tissue on its leptome-side. Inside of the bark follow, then, heavy layers of stereome, which form a solid bridge between the two sides of the angle, and which support a very large mestome-bundle. This same structure is, also, characteristic of *S. triglomerata*, *S. oligantha*, *S. Baldwini* and *S. Elliottii*. In *S. reticularis*, *S. Torreyana* and *S. ciliata*, on the other hand, the angle itself is occupied by a small group of stereome which borders inwardly on some strata of bark parenchyma in which a very small mestome-bundle is situated. Next to that occurs a large mass of stereome which connects the two sides of the angle as in *S. pauciflora*, and which supports a mestome-bundle with a hadrome of considerable development. *S. verticillata*, *S. hirtella* and *S. filiformis* illustrate a third form of structure, since the angle contains here a single, large mestome-bundle, supported by a strongly developed stereome on the leptome-side.

Some other divergencies may be observed in the relative development of the bark-parenchyma and the stereome of the stem; we notice, for instance, a very thin bark-parenchyma in *S. oligantha*, in contrast to *S. filiformis* and *S. ciliata*, where the same tissue forms strata of rather large dimensions. The stereome seems to be present in larger groups and to be more thick-walled in *S. pauciflora*, *S. Baldwini* and *S. ciliata* than in any of the other species. The pith is broken by lacunes in *S. Torreyana*, *S. reticularis* and *S. filiformis*, but is solid in the other species.

The leaf.

The leaves of our species are provided with a tubular sheath and a long linear blade, which is very narrow in the North American species with the exception of *S. triglomerata*. *Scleria* is marked by the total absence of a ligula. Projections from the epidermis, such as spines or warts, are scarce, and *S. triglomerata* seems to be the only one of our species in which continuous rows of rather sharp and curved projections are visible above the stronger ribs in the leaf-blade. Hairs are, on the other hand, common, and occur as a more or less dense pubescence upon the sheaths of all our species, or as scattered, soft hairs along the margins of the leaf-blade, besides and not infrequently upon the upper face of the blade, covering the furrows between the stronger ribs.

The anatomical structure of the leaf-blade seems to be very uniform in our species, yet exhibits some peculiarities which enable us to separate the species, at least in groups by anatomical characters. In *Scleria pauciflora* the stomata are confined to the lower face of the leaf-blade, forming longitudinal rows underneath the mesophyll. The cells of epidermis are rather large and thin-walled on both faces of the blade, and form a single group of the characteristic bulliform cells above the midrib (B C in fig. 2). The other cells of epidermis of the upper face are remarkably large, but without attaining the

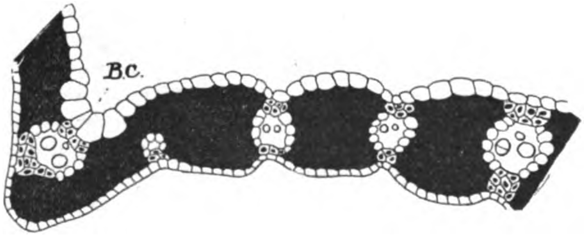

FIG. 2. Leaf of *S. pauciflora*; transverse section; B C, the bulliform cells. × 120.

shape or arrangement of proper bulliform cells. The mesophyll forms throughout a compact tissue, containing much chlorophyll and is differentiated as a palissade tissue on the upper face of the blade. Tannin-reservoirs are not uncommon in the mesophyll. Mestome-bundles of two degrees of development separate the mesophyll, which shows a distinct constriction at each bundle, as shown in the accompanying figure 2. A usual colorless parenchyma-sheath and a rather thin-walled mestome-sheath surround the bundles, the larger of which are supported by stereome on both faces, above and below. The smaller mestome-bundles show only a few stereome-cells on their leptome-side.

The same distribution of bulliform cells as representing only one group above the midrib is also met with in other species of *Scleria*, and appears to be the commonest arrangement. We have observed it in *S. triglomerata*, *S. oligantha*, *S. ciliata*, *S. filiformis*, *S. Elliottii*, *S. Baldwini* and *S. reticularis*. But in none of these species does the leaf-blade show the deep furrows which we observed in *S. pauciflora*, and which gives the section the peculiar constricted appearance. The epidermis-cells of the upper face are, however, also very large in these species, increasing in size towards one of the largest of the lateral ribs, but without becoming specialized as proper bulliform cells. It is, furthermore, characteristic of these species that one or two of the lateral ribs project very strongly on the upper face, while in *S. pauciflora* they were all situated below the surface, in shallow furrows. Stomata occur on both faces of the blade in these species, in contrast to *S. pauciflora*. Some, but slight, variations were also noticed in the thickness of the cell-walls of epidermis and stereome; we observed, for instance, a very thick-walled epidermis in *S. ciliata*, *S. Baldwini*, *S. filiformis*, and *S. Elliottii*; a thick-walled stereome in *S. ciliata* and *S. Baldwini*, besides that the mestome-sheath showed a more prominent thickening in these two species than in any of the others. *S. reticularis* is the only species in which the stereome on the upper face of the leaf-blade is separated by mesophyll from the mestome-bundles. Characteristic of the remaining three species: *S. Torreyana*, *S. hirtella* and *S. verticillata* is the presence of more than one group of bulliform cells, there being three between the larger lateral ribs in *S. Torreyana* besides the one above the midrib. In the two other species the epidermis between each two mestome-bundles and above the midrib is developed as bulliform cells, the number of groups corresponding to the width of the leaves, about four on each side of the keel of *S. verticillata*, eight or nine in *S. hirtella*. The other tissues, the mesophyll, with reservoirs of tannin, the stereome and the mestome-bundles show much the same structure as described above for *S. pauciflora*, as regards their development and distribution.

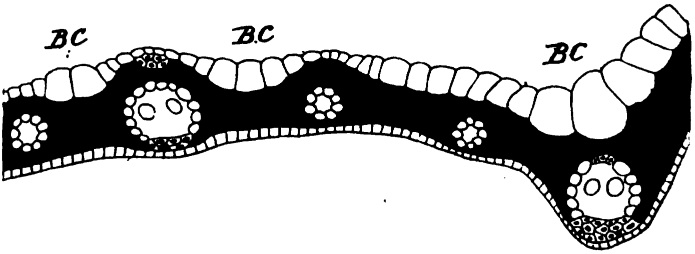

FIG. 3. Leaf of *S. verticillata*; transverse section; B C, bulliform cells. × 120.

Scleria verticillata and *S. hirtella* differ, however, from the other species of *Scleria*, which we have examined, and as a matter of fact from all the other Cyperaceæ which we have studied anatomically, by possessing some very peculiar incrustations of silica upon the radial walls of the bulliform cells. The accompanying figure 4 illustrates two bulliform cells in transverse section, with incrustations upon the radial-walls, the outline of which are indicated by dotted lines in our figure. These incrustations form granular masses of a whitish color and are present in almost all the bulliform cells, but varying somewhat in shape and size. By burning sections of the leaf to white ashes and then adding a few drops of hydrochloric acid these incrustations become very conspicuous and assume a clear brown color like sepia. Figure 5 illustrates a macerated bulliform cell, and we notice here that the incrustation has taken place to the same extent on both of the adjoining radial cell-walls. A part of the radial cell-wall upon which the incrustation takes place contains also silica and remains as fragments attached to the incrustations after they have been macerated, which is to be seen in the accompanying figure 6. Figs.

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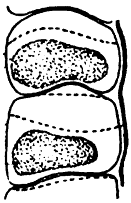

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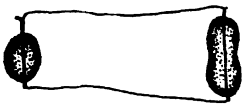

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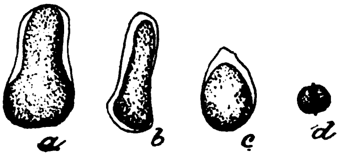

FIG. 4. Two bulliform cells from the leaf of *S. verticillata* with incrustations; transverse section. × 320.

FIG. 5. A macerated bulliform cell of *S. verticillata* with incrustations. × 320.

FIG. 6. Incrustations from bulliform cells of *S. verticillata*. × 320.

a, *b* and *c* show the incrustations as seen from within the cell with a part of the cell-wall still remaining: figure *d* represents one of the smallest incrustations, seen from above. These silicious incrustations dissolved in a concentrated aqueous solution of potassium in about forty-eight hours.

Silicious incrustations are also known to occur in the *Gramineæ*, and Dr. Aug. Grob has lately published a very important treatise of this subject.* He has, however, confined himself to the *Gramineæ*, and judging from his descriptions and figures, the incrustations which we have observed in *Scleria* differ very much from any of those that have been found in the *Gramineæ* or other monocotyledonous orders.

The pericarp of *Scleria* contains also a vast amount of silica. It lies in two distinct strata of which the outer one is built up by a homogeneous tissue of polyëdric cells; the inner part consists of a single layer of cells with very long and thin radial walls. It is the outer tissue that undergoes the incrustation, and when macerated the silicified cells form some very beautiful structures like stars, for instance, in *S. pauciflora* and others. Considered from an anatomical point of view, the North American species of *Scleria* show several characters in common; thus it does not seem probable to distinguish all the species by means of their structure alone. We have, nevertheless, enumerated the most salient points in the accompanying table, from which the anatomical characters may be readily seen, at least in some of our species.

	LEAF.					STEM.					
	Bulliform cells only above midrib.	Bulliform cells above midrib and three lateral groups.	Bulliform cells above midrib and four groups on each side.	Bulliform cells above midrib and eight or nine groups on each side.	Bulliform cells with incrustations.	Stereome separated from mestome-bundles by mesophyll.	Angle occupied by, bark-parenchyma.	Angle occupied by stereome and two mestome-bundles.	Angle occupied by stereome and one mestome-bundle.	Pith solid.	Pith with lacunes.
S. pauciflora	+	—	—	—	—	—	+	—	—	+	—
S. triglomerata	+	—	—	—	—	—	+	—	—	+	—
S. oligantha	+	—	—	—	—	—	+	—	—	+	—
S. Baldwini	+	—	—	—	—	—	+	—	—	+	—
S. ciliata	+	—	—	—	—	—	—	+	—	+	—
S. filiformis	+	—	—	—	—	—	—	—	+	—	+
S. Elliottii	+	—	—	—	—	—	—	—	—	+	—
S. Torreyana	—	+	—	—	—	+	—	+	—	—	+
S. reticularis	+	—	—	—	—	—	—	+	—	—	+
S. hirtella	—	—	+	—	+	—	—	—	+	+	—
S. verticillata	—	—	—	+	+	—	—	—	+	+	—

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* Grob, August, Beiträge zur Anatomie der Gramineen-blätter, Bibliotheca Botanica, Stuttgart, 1896, p. 34.

Although the first four of these species are not to be separated by the anatomical characters, which we have pointed out, they are nevertheless readily distinguished by their morphological; the other species seem on the other hand to be equally well distinguishable by anatomical and morphological divergences.

In considering the character of soil and climatological conditions of the localities from where our material has been brought together, one might feel inclined to designate these plants as belonging to xero- or hydro-philous societies. Their structural peculiarities, however, do not point towards any distinction of that kind. *Scleria pauciflora*, for instance, from wet ground in the vicinity of Washington, D. C., does not differ in any very marked degree from *S. triglomerata*, which we collected in dry sandy soil in subtropical Florida; furthermore *S. ciliata*, an inhabitant of the High Pine-woods of Florida, shows no strictly xerophytic characters when compared with *S. reticularis*, a bog plant. While certain species, as *S. reticularis*, *S. filiformis* and *S. Torreyana*, collected in a rather wet ground, possess a stem with a more or less broken pith, other species from similarly damp localities have perfectly solid stems. It seems as if the North American species of *Scleria* are very little susceptible to variation due to changes in environment and that they are not to be placed into any special society, either among the "xero- or hydro-phytes."

Brookland, D. C., August, 1898.

ART. IV.—*Concerning Regnault's Calorie and Our Knowledge of the Specific Volumes of Steam;* by G. P. STARKWEATHER.

THE volumes of saturated steam at various pressures customarily used are those determined from the latent heats. Since the latter depend almost entirely upon Regnault's experiments, the question of his 'calorie' is of importance. In calculating the 'heat of the liquid' and 'total heat' Regnault assumed that within the calorimeter range, say from 0° to 30° C., the specific heat of water was sensibly constant. Whether this is so or not depends upon the thermometric scale used. If mercurial it might be so, but if the scale was that of the air-thermometer, which is the one to which Regnault usually reduced his observations, it certainly would not.

Bosscha[*] in 1874 remarked that in the experiments under consideration there was no record of the calorimeter temperatures being reduced to the air-thermometer, and accordingly made corrections to Regnault's formula for 'heat of the liquid,' although he still assumed that the specific heat of water was constant within the calorimeter range. To this Regnault replied that the calorimeter temperatures were reduced to the air-thermometer, but as this was over twenty years after the experiments were conducted there has always been more or less uncertainty to many minds.

The writer hopes to present some evidence from Regnault's experiments themselves corroborating his statement, and will construct formulæ taking into account the variation of the specific heat of water from 0° to 30°. The agreement between Rowland and Griffiths[†] regarding this variation is so exact, and their methods were so accurate, that between the limits mentioned it can be regarded as determined. Their results are expressed according to the Paris nitrogen scale, but the specific heats according to Regnault's air-thermometer would not differ qualitatively from them, and ought not to differ much quantitatively. The only person, so far as the writer is aware, who has looked at the subject in the light of recent experiments is Ekholm,[‡] but he concludes (it seems to the writer incorrectly) that Regnault's calorimeter temperatures were not reduced to the air-thermometer, and accordingly makes no corrections for the variation in the specific heat at low temperatures, supposing it to be constant according to the mercurial thermometer.

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[*] Ann. Phys. und Chem., Jubelband, p. 549.

[†] Phil. Mag., xl, p. 449, 1895, and Proc. Roy. Soc., lxi, p. 479, 1897.

[‡] Bihang till Handlingar Svensk. Vet. Akad., xv, 1889, No. 6, p. 27.

Before making use of Regnault's experiments on heat of the liquid it is well to note the error discovered by Velten* in them. In Regnault's table the second column gives the weight of cold water in the calorimeter, P; the third, the weight of hot water, *p*; the seventh, the temperature, T, of the hot water according to the air-thermometer; the eighth, the initial temperature of the calorimeter, t_0; the ninth, the final temperature of the calorimeter, t_1; the eleventh (t_1-t_0) corrected; the last, the mean specific heat between t_1 and T, x. Then we should have, according to Regnault's assumption that at low temperatures the specific heat is practically constant,

$$x=\frac{P(t_1-t_0)}{P(T-t_1)}.$$

Now Velten has found that out of Regnault's forty experiments in only five does his value of x agree with this formula; in twenty-two cases the difference is insignificant, while in thirteen cases there is complete disagreement. Velten has ascribed this discrepancy to errors in calculation, but it is very strange that erroneously calculated these values of x should bear a good agreement with the others and as 'correctly' calculated by Velten should not. Sutherland† has almost conclusively shown that the error is one in the copying of Regnault's numbers into the tables, namely, that Regnault in these thirteen experiments, which belong to a different series from the others, copied a wrong set of numbers for the weight of hot water, and that his values of x are the correct ones. Sutherland's proof is based on considerations of the cubic capacity of the calorimeter, as these very experiments show an unusually large amount of hot water. In fact, as the numbers stand, there is indicated a total weight of hot and cold water greater than the capacity of the calorimeter.

The writer has made corrections to Regnault's experiments on the heat of the liquid necessitated by the variation of the specific heat within the calorimeter range, but has found that Ekholm's formula fits as well as any. Although this was formed without the above mentioned corrections, nevertheless the latter are considerably smaller than the variations in the experiments themselves. Also in developing the formula Ekholm left out certain experiments which are those the corrections affect the most. The formula is

$$h=t+0{\cdot}00000929\,t^2+0{\cdot}000000265\,t^3,$$

and is to hold only above 100°.

The unit here is the specific heat at 15° according to Regnault's thermometric scale, which will be denoted as Regnault's calorie. The formula may be incorrect towards 200° by about 0·3 per cent, but is quite accurate at 100°, since in this vicinity the corrections are very slight whatever be the thermometric scale. It gives for the mean specific heat between 0° and 100° the value 1·00358.

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* Wied. Ann., xxi, p. 45, 1884.

† Phil. Mag., xxvi, p. 302, 1888.

Now if Regnault's scale was that of the air-thermometer, this number should agree with the determinations made by other observers who have used that scale or ones not differing essentially from it. Such determinations have been made by Von Muenchausen,[*] Rowland,[†] Henrichsen,[‡] Baumgartner,[§] Velten[‖] (two series, one by the method of mixtures, the other with the Bunsen ice-calorimeter), Dieterici,[¶] Ludin,[**] Joly,[††] and Reynolds.[‡‡]

Von Muenchausen's work, which was conducted by the method of mixtures, has been criticised by Rowland on the ground that the experiments were performed in an open vessel. An inspection of his tables reveals great discrepancies. Thus as a mean of row I he finds that the mean specific heat from 26°·70 to 42°·37 is 1·0033 times that from 20°·07 to 26°·70. This is impossible, for the specific heat reaches a minimum at 32°, by Rowland's experiments, and there would be necessitated a mean specific heat from 32° to 42° of 1·0033, the specific heat at 15°, c_{15}, being the unit. This mean specific heat would indicate for c_{42} the value 1·0102, an increase of 1·4 per cent in ten degrees. Moreover in rows II and III he finds that the mean specific heat from say 25°·7 to 42°·7 is 1·0037 times that from 17°·3 to 25°·7, an increase over the preceding, whereas according to Rowland's data it should be less. His formula makes c_{0-100} equal to 1·015 c_{15}.

The writer has made careful comparisons of a similar nature of the experiments of Baumgartner and Velten, and finds even worse discrepancies. Baumgartner makes the mean specific heat from 0° to 100° equal to 1·016 c_{15}, while Velten's two series make it respectively 0·9896 and 0·9929.

The experiments of Henrichsen were performed with the ice-calorimeter. Dieterici, who is an authority on the use of this instrument, has made a careful comparison of them with those of Velten carried out by the same method. He says (reference, p. 443): "The great differences which the experiments made with the ice-calorimeter show, make it probable that this instrument is unsuited for this investigation." Moreover Henrichsen makes the ratio of the mean specific heat from 0° to 100° to that from 0° to 25° equal to 1·025, a number which is markedly larger than has been obtained by any other investigator.

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[*] Wied. Ann., i, p. 592, 1877.

[†] Proc. Amer. Academy, 1879–80, p. 120.

[‡] Wied. Ann., viii, p. 83, 1879.

[§] Ibid., viii, p. 648, 1879.

[‖] Ibid., xxi, p. 31, 1884.

[¶] Ibid., xxxiii, p. 417, 1888.

[**] Beiblaetter zu Wied. Ann., xx, p. 764, 1896.

[††] Phil. Trans., clxxxvi A, pp. 322, 323, 1895.

[‡‡] Nature, June 3, 1897.

So far we see that little or no dependence can be placed on the experiments. Rowland's work should be more reliable. His experiments make c_{25-100} equal to 1·0024 c_{15-25}, or reduced to c_{15} as a unit, c_{25-100} is 1·0049 c_{15}, which makes c_{0-100} equal to 1·0034 c_{15}. He mentions two other determinations and gives as the mean of all three that c_{0-100} is equal to 1·0041 c_{15}.

The very recent work of Ludin was performed with great care. He gives for c_{0-100} the value 1·00543 c_{15}.

Joly's determination of c_{0-100} was obtained by the use of his steam-calorimeter, and gives for its value 0·9957 c_{15}. Concerning the accuracy of this instrument we know nothing, and no details are given. He himself says he obtained much larger values in earlier experiments, but he considers this to be more accurate.

We have now left the determinations of Dieterici and Reynolds. These were both by obtaining the mechanical equivalent. Dieterici found by electrical methods (and using the ice-calorimeter) that c_{0-100} was equal to 42·436 megalergs. Griffiths* has pointed out that he made the error of using the "legal" instead of the "true" ohm, which reduces his value to 42·33. There is also a constant error† in experiments made by electrical methods of about one-quarter of one per cent due to the determination of the electrical standard of electromotive force, which reduces this to 42·225. This makes the mean specific heat between 0° and 100° equal to 1·00799 c_{15}. The experiments of Dieterici were performed with great care, were sixteen in number, and deviated from the mean at most 0·37 per cent, the probable error being 0·05 per cent. But they have one fault, that there is lacking a conclusive determination of the quantity of quicksilver displaced in the ice-calorimeter by a quantity of heat equal to the mean specific heat from 0° to 100°. Bunsen has found it to be 15·41 milligrams, Schueller and Wartha 15·442, and Velten 15·47; Dieterici takes the second value. Velten's values being uncertain, as has been shown, it seems as if less weight should be given to his determination, which would still further reduce Dieterici's value for the mean specific heat from 0° to 100°.

In total opposition to Dieterici stand the recent results of Reynolds. According to him the mechanical equivalent of the mean specific heat from 0° to 100° is 41·83 megalergs, which is equal to the specific heat at about 20°. His experiments are as concordant as those of Dieterici.

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* Phil. Mag., xl, p. 446, 1895.

† Phil. Mag., xl, p. 449, 1895; Proc. Roy. Soc., lxi, p. 479, 1897, and Johns Hopkins Univ. Circular, No. 135, June, 1898, p. 54.

Let us now compare Regnault with these other investigators. The table below gives the fractional deviations of c_{0-100} according to them from 1·00358 c_{15}.

(1) Experiments which are unreliable.

Von Muenchausen	(mixtures)	+0·0113
Velten	(mixtures)	—0·0139
Henrichsen	(ice-calorimeter)	+0·0214
Velten	(ice-calorimeter)	—0·0106
Baumgartner	(mixtures)	+0·0124
Joly	(steam-calorimeter)	—0·0079

(2) Experiments in which evidences of unreliability are not present.

Rowland	(mixtures)	+0·0005
Ludin	(mixtures)	+0·0018
Dieterici	(mech. equiv.)	+0·0044
Reynolds	(mech. equiv.)	—0·0050

The first set are grouped so far as possible into pairs of equal probability and nearly balance. Of the second set the last two balance, and the deviations in the first two are very small. As the numbers stand the positive deviations seem to rather outweigh the negative; some additional evidence on the negative side is afforded by the following: Sahulka* has found for the mechanical equivalent at 58° the value 426·262 kilogram-meters, or 41·81 megalergs, thus making c_{58} equal to 0·9981 c_{15}. Assuming the specific heat to vary linearly with the temperature from 35° to 100°, this would make the mean specific heat from 0° to 100° equal to 0·9992 c_{15}, the fractional deviation from the value we have assumed being thus —0·00436. This evidence is not entitled to very much weight, however, because Sahulka's experiments deviate from their mean over one-half of one per cent.

It is thus seen that the assumption that Regnault's thermometric scale was that of the air-thermometer makes his value of c_{0-100} agree well with that obtained by others. It cannot be more than 0·5 per cent out, and is probably much more accurate than that. Any error in it should be ascribed to the unit in which it is expressed rather than to inaccuracies in the experiments themselves.

For temperatures below 100° the writer has formed for his present purposes the following formula:

$$h = 1{\cdot}00449\,t - 0{\cdot}0001904\,t^2 + 0{\cdot}000001813\,t^3.$$

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* Wied. Ann., xli, p. 748, 1890.

Two of the constants were determined so as to make c_{18} equal to unity and c_{0-100} equal to 1·00358, while the remaining constant was adjusted to give a good value to c_{30}; the mimimum value is reached at 35°. A better agreement might be obtained by the method of least squares, but since c_{0-100} is not too well known and the remaining data all lie below 40° such nicety would not be justified. Moreover the only use made of the formula is to obtain latent heats from total heats, and also the entropy of dry saturated steam, and the term given by this formula is very small in comparison with the quantities with which it is combined.

The formulæ adopted for the heat of the liquid give us the following for the entropy of water:

$$\eta_w = a \log_{10} T - bT + cT^2 - d.$$

	Below 100°.	Above 100°.
log a	3·173436	3·015698
log b	0·156626	$\bar{1}$·250174
log c	$\bar{3}$·065024	$\bar{4}$·229792
d	3328·0	2490·9

This gives the entropy in kilogrammeters (at Paris) per degree, the zero of entropy being that of water at 0° C. T is the temperature absolute, absolute zero being taken as —273°·7 C.

Regnault's ninth memoir, Memoirs of the Institute of France, vol. xxi, furnishes us with the greater part of our knowledge concerning the total and latent heat of steam. Other experiments have been made by Andrews,* Favre and Silbermann,† Berthelot,‡ Schall,§ Dieterici,‖ Hartog and Harker,¶ Griffiths,** G. Fuchs,†† A. Svensson,‡‡ W. Ramsay and D. Marshall,§§ and Harker.‖‖ All excepting those by Dieterici, Griffiths and Svensson are at, or in the close vicinity of, 100°. Those by Hartog and Harker and by Harker alone are admitted by the authors themselves to be inaccurate. In all the remainder there is doubt as to what unit the results are expressed in, and they are few in number. Taken at their face value they all give a remarkable confirmation of Regnault's determination at 100°. The following table, taken partly from Griffiths' paper on latent heats, shows this:

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* Chem. Soc. Journal, 1849.

† Ann. de Chimie et de Phys., xxxvii, 1853.

‡ Comptes Rendus, lxxxv, 1877.

§ Berichte d. Chem. Gesell., xvii, 1884.

‖ Wied. Ann., xxxvii, p. 494, 1889.

¶ Proc. Manchester Phil. Soc., 1893–4.

** Phil. Trans., clxxxvi A, p. 261, 1895.

†† Inaug. Dissertation, Erlangen, 1894, and Beiblaetter zu Wied. Ann., xix, p. 559, 1895.

‡‡ Beiblaetter zu Wied. Ann., xx, p. 559, 1895.

§§ Rep. British Ass., 1895, p. 628.

‖‖ Mem. and Proc. Manchester Lit. and Phil. Soc. (4), x, p. 38, 1896.

Observer.	Temperature.	Number of Experiments.	Extreme values of L.	Mean L.
Andrews	100	8	530·8 –543·4	535·9
Favre and Silbermann,	99·81	3	532·59–541·77	535·77
Berthelot	100	3	535·2 –537·2	536·2
Schall	100			532·0
Fuchs	100			536·8
Ramsay and Marshall,	100			537·0
Regnault	99·88	44	533·0 –538·0	536·3

The greatest deviation of these mean values from Regnault's is about eight-tenths of one per cent. To get Regnault's latent heat from his total heat I have used the 'heat of the liquid' from the formulæ already developed.

Consider now Regnault's experiments on total heats. These are divided into four classes, those at or near 100°, those from 119° to 195°, those from 63° to 88°, and last the set from −2° to +16°. He has given as a formula to unite these

$$H = 606{\cdot}5 + 0{\cdot}305\, t.$$

Take the series at 100°, forty-four in number. Neglecting the first six, which Regnault does not regard as so accurate as the others, the mean is 636·67, and the greatest deviation from this is less than three-tenths of one per cent. If we admit the first six the greatest deviation is less than six-tenths of one per cent. When we consider the fact that Regnault purposely varied all his experiments in many ways so far as possible, in order to eliminate constant errors, this close agreement in so many experiments shows that the mean value given above is very exact.

The unit in which this is expressed is determined by the calorimeter range, the average of which was from about 8°·3 to 20°·9, from which range the individual experiments did not differ essentially. Accordingly the unit is the specific heat at 14°·6 according to Regnault's thermometric scale, or practically Regnault's calorie. This we have judged to be the specific heat at 15° according to Rowland's scale, and have investigated the possible error in that judgment. There will be accordingly the same possible error in the total heats.

Consider next the experiments above 100°, seventy-three in number. A comparison of the numbers given in Regnault's tables with those given by his formula follows: From 119° to 150° the deviations of the experiments from the formula vary from −0·36 per cent to +0·25 per cent, mostly negative, but are generally very slight. At 153°, or experiment number 32, there is a sudden jump to −0·5 per cent, and a deviation exists varying from −0·2 per cent to −0·65 per cent, averaging −0·5 per cent, and gradually increasing up to 175°·5. Here there is another sudden change, and the deviations vary up to

195° between +0·2 per cent and −0·2 per cent, mostly positive. These sudden changes are rendered much more prominent by the following table. In the first column is given the number of the experiment, in the second the temperature, and in the third the fractional deviation of the observed total heat from that calculated by Regnault's formula.

1	119·25	−·0009	−·0014	−·0011
2	119·60	−·0018	−·0018	−·0015
3	122·17	−·0025	−·0028	−·0025
4	125·2	−·0013	−·0003	·0000
5	125·5	−·0018	+·0008	−·0005
6	127·2	−·0008	+·0002	+·0005
7	129·0	−·0011	−·0001	+·0002
8	134·4	+·0024	+·0015	+·0018
9	134·2	+·0002	−·0007	−·0004
10	135·1	+·0013	+·0004	+·0007
11	135·0	+·0023	+·0014	+·0017
12	135·2	−·0002	−·0011	−·0007
13	135·5	−·0013	−·0006	−·0002
14	135·7	−·0009	−·0002	+·0002
15	136·4	−·0008	−·0001	+·0003
16	137·5	−·0016	−·0009	−·0005
17	137·7	−·0020	−·0013	−·0009
18	138·6	−·0006	+·0001	+·0005
19	142·0	−·0009	−·0002	+·0002
20	142·2	−·0016	−·0009	−·0005
21	142·5	−·0036	−·0029	−·0025
22	143·4	+·0002	+·0009	+·0013
23	144·3	−·0018	−·0025	−·0021
24	144·3	−·0013	−·0006	−·0002
25	145·3	+·0003	−·0004	+·0001
26	145·4	−·0014	−·0021	−·0016
27	145·6	−·0028	−·0035	−·0030
28	146·5	−·0002	−·0009	−·0004
29	147·6	−·0030	−·0037	−·0032
30	149·0	+·0014	+·0007	+·0012
31	150·2	+·0005	−·0002	+·0003
32	153·5	−·0050	−·0035	−·0029
33	154·1	−·0050	−·0035	−·0028
34	155·1	−·0060	−·0025	−·0019
35	155·2	−·0060	−·0045	−·0039
36	155·2	−·0028	−·0013	−·0007
37	155·3	−·0044	−·0029	−·0023
38	155·7	−·0040	−·0025	−·0019
39	156·5	−·0020	−·0005	+·0003
40	157·1	−·0046	−·0031	−·0024
41	157·8	−·0040	−·0025	−·0018
42	160·3	−·0039	−·0024	−·0016
43	160·4	−·0034	−·0019	−·0011
44	161·8	−·0030	−·0015	−·0007
45	164·6	−·0050	−·0035	−·0026
46	164·9	−·0024	−·0009	·0000
47	171·6	−·0050	−·0035	−·0024
48	172·6	−·0059	−·0044	−·0033
49	172·6	−·0059	−·0044	−·0033
50	172·8	−·0066	−·0051	−·0040
51	173·1	−·0058	−·0043	−·0031
52	173·4	−·0059	−·0044	−·0032
53	173·9	−·0056	−·0041	−·0029
54	174·0	−·0055	−·0040	−·0028
55	175·3	−·0060	−·0045	−·0034
56	175·5	−·0060	−·0045	−·0034
57	179·3	+·0016	+·0031	+·0044
58	179·6	+·0013	+·0028	+·0041
59	179·6	+·0021	+·0036	+·0049
60	180·0	+·0013	+·0028	+·0041
61	183·2	·0000	+·0015	+·0029
62	183·5	+·0005	+·0020	+·0034
63	183·7	+·0005	+·0020	+·0034
64	183·7	−·0011	+·0004	+·0018
65	186·0	+·0020	+·0035	+·0050
66	186·0	+·0026	+·0041	+·0059
67	187·9	+·0009	+·0024	+·0040
68	188·2	+·0026	+·0041	+·0058
69	188·2	+·0005	+·0020	+·0037
70	193·8	+·0006	+·0021	+·0040
71	194·2	−·0022	−·0007	+·0012
72	194·7	−·0008	+·0007	+·0027
73	194·8	+·0001	+·0016	+·0036

It is at once evident what a remarkable jump takes place at number 32. Previous to this the deviations have been both positive and negative, mostly negative, and have averaged under 0·2 per cent. Now the deviations are all negative and rarely under 0·4 per cent. But the reason for this is evident from a glance at Regnault's tables. From number 25 to 32 the calorimeter temperatures are very nearly constant, averaging 11°·5 and 23°·5, or the results are in c_{17} as a unit. Now if, as we have seen to be almost certain, Regnault's thermometric scale is that of the air-thermometer, and if we express everything in terms of the specific heat at 15° as a unit, these total heats should be a little large, since the specific heat at 17° is less than that at 15°. And it is to be noticed that three of the seven deviations in the experiments cited are positive. From precisely 32 on, however, the calorimeter measurements have all very nearly 4°·5 for the lower temperature and 18° for the upper, and the quantities of heat are therefore expressed in terms of c_{11}. Accordingly the total heats from 32 on are about 0·2 per cent too small and should be increased by that amount. This greatly smooths out the break at that place.

This point is also verified by experiments 8 to 23. In 8 to 13 the calorimeter range was 12°·5 to 24°, hence the unit is c_{18}, and the total heats should be a little large; such is seen to be the fact. In 13 to 23 the calorimeter range was 6° to 18°, the unit accordingly c_{12}, and the quantities of heat are too small. We find in fact that all the deviations except one are negative.

The first seven experiments do not bear this out quite so well. Experiments 1 to 4 are in about c_{16} as a unit, experiments 4 to 8 in about c_{12}, and hence the latter should show a slightly greater negative deviation of perhaps 0·1 per cent. This is not so, but the experiments are few in number and the deviations slight.

It should be pointed out here that it is not assumed that Regnault's formula is absolutely correct, but it is simply used as giving a smooth set of values from which to estimate the concordance of the experiments.

The writer considers that the facts here brought forward still further substantiate the essential correctness of the comparison of Regnault's calorimeter temperatures with the air-thermometer. Accordingly he has corrected Regnault's total heats so that they should all be expressed in the same unit, c_{15}, and has given in the fourth column of the table on page 20 the deviations of the total heats so corrected from those yielded by Regnault's formula. It will be seen that the formula actually fits the experiments much better than it appeared, the greatest actual deviation being about 0·5 per cent. This means in the latent heats a maximum deviation of about 0·7 per cent.

Experiments 1 to 57 indicate that the formula gives values slightly too great. At 57 there is another peculiar jump of about 0·75 per cent. The explanation of this is not so evident as in the case of number 32. It lies in the fact that as the temperatures became higher the experiments became more difficult to conduct. Regnault himself says (Memoir, p. 700) that after number 60 the apparatus required frequent repairs on account of the high temperatures. It therefore appears that the highest set of experiments, from 57 on, are of less weight than the others. If we take the ten experiments commencing with 47 which lie between 170° and 176° we find for their average fractional deviation —·0043, the maximum being

—·0051 and the minimum —·0035, the sum of the squares of the differences from the average being almost nil. If, on the other hand, we take the remaining seventeen experiments, lying between 179° and 195°, the average fractional deviation is +·0022, the maximum +·0041, the minimum —·0007. Here the extreme differences from the average are twice as great as in the preceding, while the sum of the squares of the differences from the average is considerable, thus showing their greater unreliability, apart from Regnault's own statement to that effect.

The writer has therefore considered it proper to change these average deviations by making the total heat for 190° a little smaller than that given by Regnault's formula. The equation formed is

$$H = 603{\cdot}2 + 0{\cdot}356\,t - 0{\cdot}00021\,t^2$$

to hold only above 100°. In the fifth column of the table (page 20) there are given the fractional deviations of the corrected total heats from this formula. It will be seen that up to 26 the experiments are satisfied as closely as possible. From 26 to 57 the deviations gradually increase on the negative side, while from 57 to 73 they are still more marked on the positive side. But 26 to 57 are greater in number than the latter, are more consistent in themselves, and, as we have seen, are more reliable. This justifies the greater weight given to them. The average deviation in the last seventeen experiments is +·0038. Even if the corrections due to the variation of the specific heat of water are not allowed, the formula still represents the experiments better than Regnault's.

The formula is correct at 100°, and I think we can say that at 200° it cannot be more than 0·4 per cent out, corresponding to an error in the latent heat of 0·6 per cent.

Consider now Regnault's experiments below 100°. In the first six of the twenty-three from 88° to 63° the calorimeter temperatures averaged about 7° and 19°, hence the quantities of heat are expressed in c_{13} as a unit. Experiments 7 to 13 have for a calorimeter range 9° to 21°, or are in c_{15} as a unit. The remaining experiments have the same calorimeter range as the first six. Taking account of these facts, the fractional deviations of the experiments from Regnault's formula are as given below:

	t			*t*			*t*	
1	88·11	+·001	9	81·03	—·004	17	17·1	—·008
2	87·83	+·001	10	80·60	—·005	18	70·49	—·001
3	85·97	—·006	11	80·37	—·004	19	69·70	—·001
4	85·24	—·005	12	80·17	—·001	20	68·01	—·007
5	85·20	·000	13	79·55	·000	21	66·30	—·002
6	84·88	—·005	14	78·28	—·005	22	64·33	—·004
7	83·08	—·005	15	76·50	—·001	23	63·02	·000
8	82·66	—·001	16	71·35	—·005			

It is immediately seen that Regnault's formula gives results uniformly too great. The reason is because the formula is made to fit his experiments near 0°, which we shall see to be at fault. The average deviation of the formula from the experiments is 0·3 per cent.

The experiments near 0° are undoubtedly incorrect. They were performed by a method different from that which was used in the remainder, and Regnault himself does not consider them so good as the others, indicating a number of causes of uncertainty (Memoir, pp. 716–719). Another source of error lies in the fact that Regnault supposed, in common with the physicists of his time, that the heat necessary to form vapor depended only on the final state of the vapor and not at all on the process by which it was formed. This error did not enter into the preceding sets of experiments, for in them the process was always one of sensibly constant pressure. In the present case, in order to produce the evaporation the pressure on the liquid was reduced, and the operation was accordingly not one of constant pressure.

In place of these unreliable experiments we have the recent accurate work of Dieterici. He found for the latent heat at 0° the value 596·8, the unit being c_{0-100}. This is the result of a very careful investigation. He made first a series of eight experiments, L varying from 595·74 to 597·29. He then made a better set, three in number, the extremes being 595·98 and 596·63. He still further improved his methods and in two experiments obtained 596·67 and 597·07. The probable error is ± 0·24 or ± 0·04 per cent. In terms of c_{15} as a unit the latent heat at 0° thus becomes 598·9. Svensson's determination is somewhat larger than Dieterici's, it being 599·92 in terms of c_{0-100} as a unit; it is probably not so correct as Dieterici's, as shown by the remarkable concordance in the observations of the latter. Both have the slight possible error due to the uncertainty of the constant of the ice-calorimeter, which we have seen to be about one-quarter of one per cent.

Griffiths' determinations were of the latent heat between 25° and 50°, the determinations at 30° and 40°·15 being made with particular care. They are as follows, the unit being c_{15}:

t	25	30	40	40·15	49·8
L	581·9	578·7	572·4	572·6	566·5

These give total heats lying considerably below Regnault's linear formula, in this respect agreeing with the experiments of Dieterici, Svensson, and those of Regnault himself from 60° to 90°. This strengthens the reliability of the formula we have formed for the region above 100°, it also lying below the linear formula. As any expression for the total heat must satisfy Regnault's determination at 100°, this being by far the most certain of any, the possibility of a linear formula is thus precluded, although it is evidently nearly such.

If we attempt to form an expression for H to satisfy Dieterici's value at 0°, Griffiths' values from 25° to 50°, and Regnault's value at 100°, it will make $\frac{d^2H}{dt^2}$ positive instead of negative, will not agree with Regnault's determinations from 60° to 90°, and will make an abrupt break at 100° where it joins the formula for the region above 100°. If one neglects Dieterici's determination and forms a formula to satisfy Regnault's value at 100° and Griffiths' determinations, and to join smoothly with the formula above 100°, it will give a value at 0° far below Dieterici's. The writer has therefore formed the following equation, using Dieterici's value at 0°, Regnault's H at 100°, and making $\frac{dH}{dt}$ at 100° equal to that by the formula used above 100°:

$$H = 598{\cdot}9 + 0{\cdot}442\, t - 0{\cdot}00064\, t^2.$$

A comparison of Regnault's experiments with this formula follows, the fractional deviations being given:

1	+·0018	6	−·0040	11	−·0029	16	−·0031	21	+·0002
2	+·0018	7	−·0040	12	+·0001	17	−·0061	22	−·0016
3	−·0051	8	·0000	13	+·0011	18	+·0009	23	+·0025
4	−·0041	9	−·0029	14	−·0037	19	+·0009		
5	+·0009	10	−·0039	15	+·0004	20	−·0050		

The agreement is far better than by Regnault's formula. Indeed a much better agreement could not be obtained by any formula which joins smoothly with one which fits the experiments above 100°. If there is a question as to which set of experiments to fit best, those above 100° or those below, the answer is immediately those above, for not only are the experiments below 100° in less concordance with one another, as shown by the deviations just tabulated, but Regnault himself says that they were more difficult to conduct, the boiling not taking place steadily, but in great puffs at intervals. The expression for H will be considered only as provisional, however; the subject of total and latent heats below 100° will be discussed again in another paper. The formula does not agree any too well with Griffiths' latent heats (adding to them h), the fractional deviations of the latter from the former being about −·005.

It should be observed that this formula, as well as the formula for total heats above 100°, holds independently of the judgment made that Regnault's calorie is equal to the specific heat at 15° according to Rowland. For since we know the value of the mean specific heat from 0° to 100° in terms of Regnault's calorie by Regnault's own experiments, it follows that 598·9 expresses Dieterici's determination at 0° in the same unit as that in which 636·7 expresses the total heat at 100°, be that unit c_{15} or not. Therefore the writer considers that the formula expresses the total and latent heats in Regnault's calorie with a maximum possible error of 0·5 per cent at the lower end.

Griffiths believes that the mean specific heat from 0° to 100° is almost exactly equal to c_{15}. He bases this conclusion on the following considerations: He has expressed in terms of c_{15} his latent heats, already referred to, very closely by the linear formula

$$L = 596{\cdot}73 - 0{\cdot}6010\,t.$$

Extrapolating to 0° and 100° there are obtained 596·73 and 536·63. The first is almost exactly the value of L Dieterici has found at 0° in terms of c_{0-100}, the second is what one would get from Regnault's experiments on total heat if one supposed that c_{0-100} is equal to c_{15} and that Regnault's total heat at 100° is expressed also in terms of c_{15}. Thus to support a linear formula, which type of formula is improbable in itself, he has to make two suppositions, one that c_{0-100} is the same as c_{15}, which we have seen is not the best value, and the other that Regnault's calorie is equal to c_{15}, which we have seen to be probably true. But these two assumptions are contradictory, for by Regnault's own experiments on the specific heat of water c_{0-100} is 1·00358 times his calorie.

From the formulæ for h and H the writer has obtained the latent heats and thence the specific volumes of dry saturated steam. In obtaining the latter there are also required the specific volumes of liquid water at various temperatures, the relation between the pressures and temperatures of dry saturated steam, and the value of the mechanical equivalent of heat. The specific volume of water below 100° is for as many decimal places as have been used constantly 0·001 cubic meters per kilogram. Above 100° Hirn's* formula has been adopted. For the relation between pressure and temperature Regnault's formula H has been used above 100°, while below 100° his formula C (with the constants as recalculated by Zeuner) is taken. These should be sensibly correct except below 40°, where an error exists due to the fact that Regnault did not know of the sudden change in $\frac{dp}{dt}$ at 0°. The value of the mechanical equivalent is taken as 427·03 kilogrammeters (at

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* Ann. de Chimie et de Phys. (4), x, p. 32, 1866.

Paris) at 15° C., according to Rowland. This determination has been strongly corroborated by recent experiments.* The volumes follow:

t	0	10	20	30	40	50	60
V	208·94	107·88	58·505	33·198	19·637	12·063	7·6703
t	70	80	90	100	110	120	130
V	5·0320	3·3942	2·3464	1·6587	1·1973	0·88099	0·65948
t	140	150	160	170	180	190	200
V	0·50152	0·38707	0·30278	0·23982	0·19216	0·15566	0·12739

Consider the possible errors in these. They may first have an error of not exceeding one-half of one per cent due to the determination of Regnault's calorie in kilogrammeters; however much this may be, it is constant for all the V's. Aside from this there may be an additional error due to our uncertainty as to the latent heats. This amounts to ± 0·6 per cent at 200°, is practically zero at 100°, and is ±0·5 per cent at 0°. Below 40° the V's are entirely uncertain owing to the errors there in p and $\frac{dp}{dt}$ already mentioned.

In volumetric experiments on steam there is an unusual amount of difficulty on account of condensation on the walls of the vessel containing it. This condensation increases very rapidly as the saturation line is approached, and as a consequence all direct determinations of saturation volumes are far less reliable than those calculated from the latent heats, for Regnault so arranged his experiments that this source of error was entirely avoided. An exception should be made of the determination of the volume at 0° by Dieterici,† in which more confidence can be placed, not only from the concordance of his results, but also from the fact that corrections were made for condensation.

On superheated steam experiments have been made by Regnault,‡ Fairbairn and Tate,§ Hirn,‖ Horstmann,¶ Herwig,** Meyer,†† Battelli,‡‡ and Ramsay and Young.§§ A large number of observations prior to Regnault's are not included here; these are all at very low pressures, hence large volumes, for which the substance can be treated as a perfect gas.

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* Johns Hopkins Univ. Circular No. 135, June, 1898, p. 54.
† Wied. Ann., xxxviii, p. 1, 1889.
‡ Mem. of the Inst. of France, vol. xxi, p. 700, 1847.
§ Phil. Trans., clii, p. 591, 1862.
‖ Théorie Mécanique de la Chaleur.
¶ Liebig's Annalen. Supplemental Band, vi, p. 51.
** Pogg. Ann., cxxxvii, p. 592, 1869.
†† Chem. Berichte. 1877, p. 2068.
‡‡ Mem. R. Acc. Sc. Torino, (2), xliii, 1893.
§§ Phil. Trans., clxxxiii A, p. 112, 1892.

For comparison of the experiments the following principles have been used: $\frac{pv}{T}$ should never exceed its limiting value for indefinite superheating; for two experiments in which the pressures and temperatures do not differ much, $\frac{pv}{T}$ should be almost the same (it would be constant for a perfect gas); $\frac{pv}{T}$ at constant pressure should be greater at greater volumes or temperatures, at constant volume it should be greater at greater temperatures or pressures, and at constant temperature it should be greater at greater volumes or lower pressures. The best determination of the limiting value of $\frac{pv}{T}$ as calculated from the chemical composition of water is that given by Van Laar,* but since he places the absolute zero at −273°·2 C. instead of −273°·7, the writer has modified his value to correspond, the number obtained being 3·4673, under the assumption that p is in millimeters of mercury and v in cubic meters per kilogram.

In this manner the writer has made careful comparisons of the various experiments. Those of Regnault were all at such low pressures that the substance should behave as a perfect gas, which probability is well corroborated by them. The single determination of Meyer is evidently incorrect, as it gives a value of $\frac{pv}{T}$ of 3·472 in a region where the deviation from a perfect gas should be fully two per cent.

The experiments of Fairbairn and Tate have in general pressures far lower than those of the others, but temperatures nearly as high; accordingly $\frac{pv}{T}$ should be much greater, whereas it runs far less. Of their twenty-three experiments six are comparable by the preceding principles with those of Hirn, Horstmann, Herwig and Battelli, four more with those of Hirn, Horstmann and Herwig, four with Herwig and Battelli, and four either with Herwig or Battelli. In almost every case the values of $\frac{pv}{T}$ run from two to five per cent less than they should for any agreement whatsoever, and accordingly there must have been considerable condensation.

Hirn's experiments yield great discrepancies among themselves. In seven of his twenty-two experiments, in which $\frac{pv}{T}$ should steadily increase, the values run

3·376 3·390 3·366 3·367 3·337 3·345 3·398

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* Zeitschr. für Phys. Chem., xi, p. 433, 1893.

Similarly the numbers should increase in each of the following columns :

3·347	3·341	3·350	3·361
3·382	3·350	3·382	3·362
3·392	3·286	3·355	3·345
3·362	3·361	3·337	

There are a few other discrepancies, but these involve one-half of his experiments, and it is difficult to get any concordance by throwing out a few of the experiments. That there was a tendency towards condensation is shown by the fact that in four of his experiments the value of $\frac{pv}{T}$ is less than is given by the saturation line for the same pressure, the difference being more than can be allowed by any error in the latter.

Suppose we ascribe these discrepancies to condensation, throwing out accordingly about nine experiments. The remainder are so few that they are only useful as a corroboration of others. Three of them are comparable with both Horstmann and Battelli and deviate from Horstmann about one per cent, from Battelli about one-half per cent, and this is in a region where the deviation from a perfect gas is only about 2½ per cent. Five others are comparable with Battelli. Of these two are in agreement, one deviates about ½ per cent, and the other two deviate 2 per cent. In the last two the total deviation from a perfect gas is about 6 per cent.

Of Horstmann's four experiments one is shown to be incorrect by a comparison with the others. The remaining three agree fairly well with Battelli.

Herwig himself discards fifty-five of his seventy-five experiments as showing condensation due to too near an approach to the saturation line. Of the remaining twenty, fourteen are in a region where the substance should behave sensibly as a perfect gas. Of the other six, five are comparable with Battelli. Two are in agreement, while the other three give deviations of 0·6 per cent, 1 per cent, and 2·5 per cent.

We thus see as general conclusions from the foregoing that among the experiments of Regnault, Fairbairn and Tate, Hirn, Horstmann, Herwig and Meyer, we have available thirteen by Hirn, three by Horstmann, and six by Herwig. So many of Hirn's and Herwig's had to be thrown out as to render the others doubtful, but even accepting them we have found that in the only comparisons which can be made, those of Horstmann and Hirn, there is some disagreement, and the experiments are not sufficiently numerous to give an accurate idea of the deviation of steam from a perfect gas in various regions. Nor are they useful as corroboration of Battelli's experiments, for of the twenty-two only seven agree with his, six are not comparable, four disagree slightly, and five disagree completely.

We have thus left only the experiments of Battelli and those of Ramsay and Young. Some at least of the determinations of the former at low pressures are incorrect, for they give values of $\frac{pv}{T}$ which differ too much from a perfect gas. In the case of Ramsay and Young we are confronted by a difficulty at the very start. I take the following quotation from them (reference, p. 122):

"The weight of the water in the tube was ascertained by determining the products of pressure and volume, altering the volumes; and this was repeated at different temperatures. Assuming that if these products for any one temperature were constant, the density of the steam was constant, viz: the theoretical density, 9, the weight could be ascertained by the equation

$$W = \frac{\text{Vapor density} \times p.\ v \times 273}{11{\cdot}1636 \times 1000 \times 760 \times (273 + t)}.$$

This expression simplifies to

$$\log W = \log p.\ v + \bar{4}{\cdot}46179 - \log (273 + t).$$

"During the progress of the experiments it happened that a trace of water passed up the tube, adding itself to that already present. This, of course, increased the weight, hence new measurements were made to determine the amount of the increase."

Thus were made the determinations of the weight of water in the tube, one the mean of experiments where the temperatures were 220° and 230°, the pressures ranging from 2500^{mm} to 3800, in the second the temperatures were 230°, 240° and 250°, the pressures ranging from 2600 to 4000, and in the third the temperatures were 250°, 260°, and 270°, the pressures ranging from 2800 to 4300. Now evidently at such pressures and volumes (the greatest specific volume came out 0·676) it is impossible that the steam can be in the condition of a perfect gas, and accordingly the determination of the weight in each of the three series is incorrect, and the volumes given by Ramsay and Young should be diminished. The errors in the three sets are probably very close to the same amount, for although the increase in temperature would mean a decrease in the error due to the assumption that the steam comported itself as a perfect gas, nevertheless the specific volumes in the three sets used for the determination of the weight diminished enough to offset this.

Assuming then this constant error in Ramsay and Young's determinations, let us make a comparison of such of them as lie near Battelli's with his. Below is given a table of the fractional deviation, *d*, of $\frac{pv}{T}$ according to Battelli from that according to Ramsay and Young; in each case the experiments compared had very nearly the same values of *p* and *T*. Above each value of *d* is given a number for reference.

No.	1	2	3	4	5	6	7
d	+·009	+·006	+·020	+·021	−·006	+·003	+·005
No.	8	9	10	11	12	13	14
d	+·010	+·027	+·090	−·017	−·013	−·016	−·015
No.	15	16	17	18	19	20	21
d	−·014	−·007	+·013	−·021	−·019	−·020	−·017
No.	22	23	24	25	26	27	28
d	−·012	−·020	−·023	−·030	−·012	0	+·009

Nos. 2, 3, 4 were all at one temperature, about 150° C., while 5 to 11 were at 180°, 11 to 18 at 200°, and the remainder at 230°.

The sudden changes in the values of *d* in 9 and 10 from those in 5 .... 8, in 16, 17 from those in 11 ... 15, and in 26, 27, 28 from those in 18 .... 25, can all be accounted for by condensation, since Ramsay and Young's figures, as will be shown, give marked evidence of condensation as the saturation line is approached, while those of Battelli do not. But the remarkable fact is that in the first eight, with the exception of the fifth, the deviations of Battelli from Ramsay and Young are all positive, the reverse of what is due to the error in the latter already mentioned. Suppose we ascribe this to large condensation in the case of Ramsay and Young. Looking at 11 .... 28 we see that the constant error in their experiments must amount to 1·5 per cent, hence in the first eight there must have been condensation to the amount of 2·5 per cent.

But there are a few experiments below 100° which can be compared, and in that region Ramsay and Young's experiments do not have the constant error already mentioned, the weights being measured directly. These follow:

	Ramsay and Young.			Battelli.		
p	45·47	39·95	35·3	67·57	85·32	100·27
v	26·06	30·15	33·57	17·851	14·1326	12·0335
T	348·7	348·7	348·7	352·24	352·24	352·24
$\frac{pv}{T}$	3·415	3·454	3·399	3·424	3·423	3·422

Now Ramsay and Young observed that there was far more condensation below 100° than above, so much so that they themselves admit that the larger part of their low temperature determinations are worthless. Therefore those given above should have at least 2·5 per cent condensation; hence, Battelli's determinations being correct, $\frac{pv}{T}$ by Ramsay and Young should be, perhaps not 2·5 per cent smaller than by Battelli, for the latter's volumes are smaller, but certainly 1·5 per cent smaller. Instead of that the smallest of Ramsay and Young's is only 0·8 per cent smaller than the greatest of Battelli's, while one of them is larger than any of the latter. We thus see that the supposition that the deviations in 1 . . . . 8 are due to condensation on the part of Ramsay and Young involves us in difficulties. At any rate they show conclusively that in the region considered either Ramsay and Young or Battelli is entirely in error.

Further, Ramsay and Young's experiments 11 . . . . 28 have all the same weight of water with the exception of Nos. 20 and 22, and hence should have a practically constant deviation to check with Battelli's. Nos. 11 . . . . 15 have such a constant deviation of about 1·5 per cent, while Nos. 18, 19, 21, 23 . . . . 26 have a fairly constant deviation of about 2 per cent, different from the former. Hence we see that the two investigations are entirely out of accord. One of them is incorrect, perhaps both.

We will therefore next examine Ramsay and Young's experiments by themselves. First they discard all their experiments below 75° C. as untrustworthy. At 75° their determinations show consecutive variations as high as 1·6 per cent. Above 100° C. there was a great deal of condensation in every case as the saturation line was approached; this is shown by the rapid increase of vapor density with increasing pressure. Thus at 140° C. total condensation occurred at a pressure of 2645^{mm}; the saturation pressure for that temperature is 2717. At 150°, 160°, 180°, 190° and 200° total condensation occurred at pressures of 3442, 4571, 7444, 9337 and 11505^{mm} respectively; the corresponding saturation pressures are 3581, 4651, 7546, 9443 and 11689^{mm}. Aside from this the density showed an impossibly rapid increase before condensation.

There are some other discrepancies in Ramsay and Young's observations which will merely be mentioned. Thus if comparison is made of those experiments at temperatures 270°, 260° and 250° for which the volumes are given as 0·644, 0·585, 0·529, and 0·435, it will be found that at constant volume $\frac{pv}{T}$ decreases with increasing temperature, which is impossible. The experiments below 250° at these same volumes, as well as at others, make $\frac{pv}{T}$ at constant volume increasing with increasing temperature, which is correct; but the increase is so rapid as to look a little suspicious. According to Battelli the increase is very slow.

Even if Ramsay and Young's experiments are substantially correct far from the saturation line, they cannot be used, for they contain a constant error, the incorrect determination of the weight of water present in the tube. There is no agreement with Battelli by which this error can be estimated, nor can we determine it from our saturation volumes already obtained, since in Ramsay and Young's experiments near the saturation line great condensation occurred.

We have left therefore only Battelli. In a table below is given a comparison of $\frac{pv}{T}$ according to such of his experiments as lie near the saturation line with that according to Regnault's experiments, the volumes being calculated from the latent heats. Each of the latter is given immediately under that one of Battelli's which is to be compared with it, and the fractional deviation of $\frac{pv}{T}$ is given last.

p	129·14	330·78	749·12	2060·1	3061·9	7971·4	12181·
T	330·7	352·2	373·33	404·01	417·94	456·6	475·71
$\frac{pv}{T}$	3·413	3·411	3·392	3·373	3·350	3·276	3·210
p	148·79	354·62	760	2030·3	2717·6	7546·4	11689
T	333·7	353·7	373·7	403·7	413·7	453·7	473·7
$\frac{pv}{T}$	3·420	3·403	3·373	3·317	3·294	3·196	3·143
d	−·002	+·002	+·006	+·017	+·017	+·024	+·021

It is at once seen that the discrepancy is very bad. Were the deviations negative instead of positive they could be ascribed to condensation in the case of Battelli, and his experiments not near the saturation line would still be available. Let us now see, supposing Battelli to be correct, where an error in our saturation volumes can be placed. We have seen that the greatest error which can possibly be ascribed to the mechanical equivalent of Regnault's calorie is 0·5 per cent. This would make the deviations respectively

−·007 −·003 +·001 +·012 +·012 +·019 +·016

Further we have seen that the latent heat at 200° C. may be at most 0·6 per cent too small, although at 100° C. it is correct. Allowing errors in the latent heats the deviations become

−·007 −·003 +·001 +·010 +·010 +·014 +·010

The two negative ones, at low pressures, could be ascribed to condensation on Battelli's part, but the remainder of course cannot.

So far we have assumed Regnault's p and $\frac{dp}{dt}$ to be correct, and we see it is impossible to get any agreement with Battelli. If we allow an error in Regnault's p and $\frac{dp}{dt}$, we must take them according to the formula Battelli gives to fit his own experiments on corresponding saturation pressures and temperatures, for we are going on the supposition that his work is correct. The change in $\frac{dp}{dt}$ changes the saturation volumes, so $\frac{pv}{T}$ is doubly changed. The deviations then become

+·023 +·006 +·018 0 +·007 +·013 +·019

and things are made worse rather than better.

It is thus a question of whether to discard Regnault's data entirely, or Battelli's. Regnault's results, with the exception of total heats at low temperatures, have received essential corroboration from almost every one who has gone over the same ground, and this is especially so concerning saturation pressures and temperatures. On the other hand, Battelli's saturation pressures deviate considerably from those of all other observers, we have seen that in some of his volumetric experiments at low pressures errors exist, and that finally there is practically no corroboration between his volumetric experiments and those of other investigators.

The writer therefore concludes that all our knowledge concerning the density of steam is limited to the saturation line, the experiments on superheated steam presenting discrepancies which cannot be reconciled.

ART. V. — *The Estimation of Boric Acid;* by F. A. GOOCH and LOUIS CLEVELAND JONES.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXVII.]

THE estimation of boric acid by treating the salts of that acid with sulphuric acid, distilling with methyl alcohol, evaporating the distillate over magnesium oxide, igniting and weighing, was proposed by Rosenbladt.* A little later, and without knowledge of Rosenbladt's experience, a somewhat similar process,† which consisted in the treating of the compound of boric acid with acetic acid or nitric acid, distillation with methyl alcohol, evaporation of the distillate over calcium oxide, and ignition of the residue, was described by one of us. In the course of the development of this process, it transpired that the insolubility of magnesium oxide retards the absorption of boric acid by that substance, and that the more soluble calcium oxide retains boric acid more actively and is therefore to be preferred.

Points in the treatment upon which special emphasis was laid in the original description of this process were the choice of a suitable apparatus for the distillation, the employment of a loosely stoppered receiver for the reception of the distillate upon slaked lime, the careful removal of water from the substance in the retort before acidifying and treating with the methyl alcohol, regulated use of acid, and care in the evaporation and ignition.

The attainment of good results in this process depends upon attention to details. Modifications have been suggested by several investigators. Thus, instead of igniting the calcium oxide in a large platinum crucible, transferring it to the receiver to hold the boric acid, and returning the calcium oxide with the distillate to the same crucible for subsequent ignition of the residue, as was originally proposed, Penfield‡ prefers to ignite the calcium oxide in a small crucible, to collect the distillate in ammoniacal water, to evaporate the latter over the calcium oxide in a large platinum dish, and to transfer this residue back to the small crucible for the final evaporation and ignition. Kraut§ suggests a modification of form in the apparatus with no other essential change in conditions. Moissan‖ has suggested changes in the apparatus and avoids a transfer of the calcium oxide—collecting the distillate by itself in a closed receiver, trapped with an ammonia bulb to prevent the escape of the boric acid from the distillate. Furthermore, Moissan's process calls for the use of an amount of calcium oxide from fifteen to twenty times greater than that theoretically required.

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* Zeitschr. für Anal. Chem., xxvi, 21.

† Am. Chem. Jour., ix, 23.

‡ This Journal, xxxiv, 222.

§ Zeitschr. für Anal. Chem., xxxvi, 3.

‖ Compt. Rend., cxvi, 1084.

From our experience it seems obvious that the demand for this amount of calcium oxide arises from an excessive use of nitric acid in the retort and the consequent modification of conditions in the distillate. Fortunately this difficulty may be avoided by the use of a little phenolphthalein as an indicator in the retort and care to limit the addition of nitric acid to the amount required to produce distinct acidity. The addition of a drop of the acid and another of the indicator should be repeated once or twice during the distillation to insure the replacement of the acid volatilized from the salt slightly decomposed in the process. The effect of much nitric acid is bad, not only because it neutralizes the calcium oxide when it passes to the distillate, but because when it is used a tendency is developed on the part of the dried mixture of calcium hydroxide and borate to puff explosively if this ignition is begun as soon as the residue is dry. If the residue is heated gradually and as strongly as possible over a radiator before the flame is actually applied to the crucible, no such action takes place; we are disposed to attribute it to the effect of the nitrate and nitrite, produced by the absorption of nitrous fumes in the lime, upon the alcohol or other organic matter retained by the lime in the evaporation and drying unless the latter process is prolonged at high temperature.

That good results may be obtained with small amounts of calcium oxide provided care as to the use of nitric acid and the conditions of ignition be taken, is shown by the figures of the original description and by the following experiments, in which phenolphthalein was employed as an indicator and the residue heated strongly over the radiator before actual ignition.

CaO taken.	B_2O_3 taken.	B_2O_3 found.	Error.
grm.	grm.	grm.	grm.
2·3405	0·1788	0·1792	+0·0004
1·7620	0·1790	0·1785	—0·0005
2·1757	0·1824	0·1840	+0·0016
2·5656	0·1788	0·1786	—0·0002

These results are accurate within reasonable limits. On the other hand, without care to ignite gradually we have noted errors of from 0·0030 grm. to 0·0060 grm. in the process otherwise conducted similarly. Doubtless the use of large amounts of calcium oxide as suggested by Moissan may serve the purpose of diffusing the explosive mixture through a mass of inert matter sufficient to prevent violent puffing, but care to heat over the radiator as strongly as possible before opening the flame directly to the crucible answers the same end. The difficulty does not exist when acetic acid is used in place of nitric acid, though even in this case it is safer to use the radiator in the first stages of heating, thus avoiding the danger of mechanical loss by too rapid ignition.

Following are determinations made by this method with the use of acetic acid.

CaO taken. grm.	B_2O_3 taken. grm.	B_2O_3 found. grm.	Error. grm.
0·9977	0·2065	0·2062	−0·0003
1·0220	0·2067	0·2070	+0·0003
1·3717	0·2077	0·2075	−0·0002
1·1310	0·1791	0·1795	+0·0004

The results of the preceding table, as well as those of the investigators mentioned, are a sufficient answer to the criticism of Reischle,* that acetic acid and nitric acid do not liberate boric acid in the distillation process so that good results may be obtained. Moreover, it has been shown by one of us† that even carbonic acid is strong enough to bring about complete volatility of boric acid with methyl alcohol.

The use of Calcium Oxide as a Retainer.

Quite recently Thaddeeff‡ has advocated the abandonment of calcium oxide as an agent for holding boric acid in the evaporation of alcoholic and aqueous solutions on account of the hygroscopic nature of the oxide and the consequent difficulty of securing it in definite conditions for weighing, and proposes, instead of using calcium oxide, to retain and estimate boric acid in solution by converting it into the form of potassium borofluoride.

In the final modification of Thaddeeff's method the proposal is made to liberate the boric acid from its compounds by sulphuric acid, to volatilize it in methyl alcohol with the aid of a current of dry air, to catch the distillate in potassium hydroxide, to treat the mixture of hydroxide and borate with hydrofluoric acid in excess and evaporate in the steam bath, to digest the residue of fluoride and borofluoride at normal temperatures for two hours with 50^{cm^3} of a potassium acetate solution (sp. gr. 1·14) and for twelve hours more after adding 100^{cm^3} of ethyl alcohol (sp. gr. 0·805), to filter on paper, wash the residue with $62–72^{cm^3}$ of alcohol (sp. gr. 0·805), dry at 100° and weigh as potassium borofluoride, after which the borofluoride is to be dissolved in boiling water and tested with calcium chloride for possible contamination by the presence of a fluoride. Plainly Thaddeeff's procedure presents at the outset difficulties; for besides the inconvenience of conducting long digestions with reagents of regulated strength, the difficulty of procuring hydrofluoric acid free from silica, which if present (as it usually is, in the so-called chemically pure hydrofluoric acid of commerce) would be retained in the borofluoride as potassium fluosilicate, the inaccuracy of the dried paper filter, and the obvious uncertainty of success in an attempt to wash a mixture of acid potassium fluoride and potassium borofluoride in potassium acetate and alcohol, so that the one shall be rendered entirely soluble while the other remains sensibly unaffected,—besides these objections, there is the theoretical probability that boric acid must be lost by volatilization during the evaporation of the solution of the mixed salts in the presence of free hydrofluoric acid. This last point was put to the proof by submitting to distillation in a platinum retort a mixture of equal quantities of borax and potassium hydroxide with an excess of hydrofluoric acid, collecting the distillate in potassium hydroxide, evaporating it to dryness and testing it for the presence of boric acid. When this residue from the evaporated distillate was treated with sulphuric acid and methyl alcohol, the burning alcohol vapor gave plainly the green flame of boric acid. Another portion showed clearly the presence of boric acid when acidulated with hydrochloric acid tested with turmeric paper. No boric acid could be detected in any of the reagents used. It is plain, therefore, that boric acid does volatilize upon the evaporation of a mixture of potassium fluoride and borofluoride in acid solution. The amount of such loss is disclosed in the record of the following experiment. Portions of a standard solution of boric acid, prepared by dissolving a known weight of anhydrous boric oxide in a liter of water, were mixed with a solution of potassium hydroxide (free from silica and standardized by conversion to the chloride) in the proportions to form the potassium borofluoride, and an excess of hydrofluoric acid was added. The mixture was evaporated and the residue was dried and weighed at 100°, the whole operation being conducted in platinum.

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* Zeitschr. für Anal. Chem., xxvi, 512.

† Jones, this Journal, v, 442.

‡ Zeitschr. für Anal. Chem., xxxvi, 568.

HKF_2 equivalent to KOH taken. grm.	B_2O_3 taken. grm.	$KFBF_3$ theoretical weight. grm.	$KFBF_3$ found. grm.	Error in terms of $KFBF_3$. grm.	Error in terms of B_2O_3. grm.
0·3531	0·1582	0·5701	0·5580	—0·0121	—0·0033
0·3192	0·1430	0·5154	0·5100	—0·0054	—0·0015
0·3192	0·1430	0·5154	0·5030	—0·0124	—0·0034
0·3192	0·1430	0·5154	0·5088	—0·0066	—0·0018
0·3192	0·1430	0·5154	0·5114	—0·0040	—0·0011

In experiments (1) to (3) the volume of the solution evaporated was about 50^{cm^3}. In experiment (4) this volume was reduced about one-half before acidifying with hydrofluoric acid, while in experiment (5) the solution was diluted about one-half before adding the hydrofluoric acid. It is plain, therefore, that in this single step of Thaddeeff's process there is a considerable error of deficiency. On the other hand, the errors for the full process as laid down by Thaddeeff have been in our experience invariably differences of excess—presumably because the loss due to volatilization of boric acid has been overbalanced by the inaccuracy in washing. It is plain that the process can give true indications only by the balancing of considerable errors.

If we take into consideration, therefore, the inevitable inaccuracy and inconvenience of Thaddeeff's proposal, it cannot be regarded as a desirable substitute for the process according to which boric acid is absorbed and retained for weighing with calcium oxide, especially since the difficulties in the way of getting constant weights of that substance are by no means insuperable.

Thus the following table shows the series of weights taken in several experiments in bringing calcium oxide to a constant weight in a 50^{cm^3} platinum crucible ignited over a blast lamp, as well as the weight taken after adding a known amount of standard boric acid solution to the slaked oxide, evaporating, and igniting. The results recorded are those of experiments made on days not moist beyond the average and with the greatest care to approach the limit of accuracy with which calcium oxide and the boric acid held thereby can be weighed under ordinarily favorable conditions. The first weight of calcium oxide recorded under each experiment was taken after a strong ignition over the blast lamp for about one-half hour. The succeeding weights were taken after similar ignition of five minutes. In all cases the crucible was left to stand a definite period in a sulphuric acid dessicator, and, after the approximate value had once been obtained, the weights of the preceding weighing were replaced on the balance before the crucible was taken from the dessicator. The average of the weights bracketed is the weight taken as constant for the calculations.

	CaO taken. grm.		B_2O_3 taken. grm.	$CaO + B_2O_3$ taken. grm.	$CaO + B_2O_3$ found. grm.		Error. grm.
(1)	0·9505				1·1590	1·1591	+0·0003
	0·9493	0·9493	0·2095	1·1588	1·1591		
	0·9493						
(2)	1·1319				1·3499		
	1·1317	1·1315	0·2150	1·3465	1·3474	1·3475	+0·0010
	1·1313				1·3475		
	1·1315				1·3476		
(3)	0·8028				0·9205		
	0·8025	0·8024	0·1184	0·9208	0·9206	0·9206	+0·0002
	0·8024				0·9206		
(4)	2·6980						
	2·6975				2·9043		
	2·6973	2·6973	0·2073	2·9046	2·9049	2·9048	+0·0002
	2·6973				2·9044		

Obviously calcium oxide may be weighed with accuracy, with or without boric acid; but the fact remains that a less hygroscopic absorbent—one requiring less care in the handling, is to be desired.

The use of Sodium Tungstate as a Retainer.

In searching for a suitable material of less hygroscopicity to replace calcium oxide as a retainer for boric acid, we have found that sodium tungstate, fused with a slight excess of tungstic acid over that contained in the normal tungstate (to insure its freedom from carbonate), answers this purpose excellently. This substance is definite in weight, not hygroscopic, soluble in water, and recoverable in its original weight after evaporation and ignition. To test its value as a retainer for boric acid, portions of it—4 to 7 grms.—were fused and weighed in a 50^{cm^3} crucible, the tungstate was dissolved in water and to it was added a known amount of a standard solution of boric acid. After diluting, mixing, evaporating, and fusing the residue, the increase in weight should represent the boric anhydride held by the tungstate. The results of the accompanying table show how accurately the boric acid is retained under these conditions: In experiments (3) to (7) the tungstate, after its first weighing, was dissolved, transferred to a larger platinum dish and mixed therein with the boric acid. After evaporation to a suitable volume this solution of tungstate and boric acid was transferred to the original crucible for final evaporation and ignition.

$Na_2WO_4+WO_3$ taken. grm.	B_2O_3 taken. grm.	B_2O_3 found. grm.	Error in B_2O_3. grm.
6·5416	0·1784	0·1771	−0·0013
7·3134	0·1786	0·1773	−0·0013
5·5003	0·0950	0·0952	+0·0002
4·1394	0·0944	0·0944	0·0000
7·5037	0·2148	0·2149	+0·0001
4·7744	0·2718	0·2702	−0·0016
6·6470	0·2503	0·2487	−0·0016

It is plain that though the sodium tungstate does not hold the boric acid with absolute accuracy the errors are not unreasonable −0·0008 grm. in the mean. Upon substituting the tungstate for calcium oxide as a retainer in the distillation process, the results were likewise highly favorable.

We used by preference the apparatus originally proposed, excepting that the Erlenmeyer flask used as a receiver is fitted tightly to the condenser and trapped with water bulbs. The retort is made very easily from a 150^{cm^3} pipette and has the special advantage that particles of the residue spattering during distillation are easily washed from the walls of the vessel by a slight rotary motion of the retort. It was found that special care should be taken to give the tungstate ample time for contact with the distillate before exposing the latter to atmospheric evaporation. The distillate was received, therefore, in a dilute solution of sodium tungstate placed in the receiver, cooled by ice and trapped with water, and the mixture was well stirred, allowed to stand one-half hour, evaporated to small volume in a large dish, and transferred to the crucible in which the tungstate had been originally weighed. After thorough drying the residue was ignited to fusion and weighed. When acetic acid was employed in the retort, care was taken in the ignition to expose the fused mass freely to the air (by causing it to flow upon the sides of the crucible) until the color of the cooled tungstate was white, in order that the reducing effect of the acetate might be eliminated. In the experiments recorded in the following table the tungstate was used in the receiver to retain the boric acid distilled as usual with methyl alcohol, from the borates treated with acetic acid, nitric acid or sulphuric acid, in amounts regulated by the use of phenolphthalein as an indicator.

$Na_2WO_4+WO_3$ taken. grm.	B_2O_3 taken. grm.	B_2O_3 found. grm.	Error grm.
	With Nitric Acid.		
8·5516	0·1582	0·1572	−0·0010
4·9639	0·1329	0·1323	−0·0006
8·0033	0·1267	0·1256	−0·0011
	With Acetic Acid.		
4·9658	0·1434	0·1418	−0·0016
6·0289	0·1431	0·1433	+0·0002
4·6797	0·1589	0·1587	−0·0002
4·0013	0·1433	0·1422	−0·0011
	With Sulphuric Acid.		
6·3439	0·1582	0·1579	−0·0003
8·8227	0·1582	0·1577	−0·0005
10·1516	0·1265	0·1264	−0·0001
6·5738	0·1392	0·1390	−0·0002

Excessive use of acid is disadvantageous, and this is especially true in the case of sulphuric acid; for, if this acid is carried over with the methyl alcohol, as it is at 100° if present in appreciable excess, a part of it, at least, is held permanently by the tungstate to increase the apparent weight of the boric acid to be estimated.

The manipulation of the tungstate presents no difficulties, and the results obtained by its use are reasonably accurate.

ART. VI.—*Descriptions of imperfectly known and new Actinians, with critical notes on other species*, II.; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College*, No. LIX.

Family HALOCLAVIDÆ Ver. nov.

COLUMN much elongated, either smooth or with suckers; base with a very small or rudimentary disk; tentacles 20, obtuse or capitate; ten pairs of mesenteries, all perfect.

Haloclava, gen. nov. Type *H. producta* (Stimp.) Ver. Figure 7.

Column much elongated, soft, without a sheath, the upper part with rows of distinct adhesive suckers. Upper end with a sphincter and capable of involution. Aboral end often inflated or bulbous, with a rudimentary disk, capable of adhesion to small pebbles. Tentacles twenty, short, usually clavate, nearly equal, marginal. Mesenteries very muscular, all perfect, arranged in 10 pairs; six of these pairs are larger and form a regular primary cycle; four other pairs, narrower below, belong to the second cycle; the usual pair, next to the ventral or sulcar pair of directives, is lacking on each side.

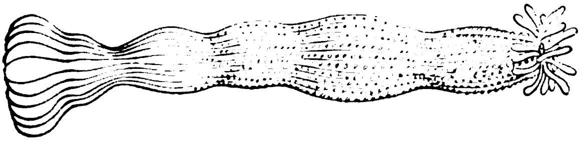

Fig. 7.

Besides the type species this genus will include *H. albida* Ver., which I now consider only a variety. *H. Capensis* Ver., Commun. Essex Inst., v, p. 5, pl. 3, fig. 7, 1869;* *H. brevicornis* (Stimp.) Ver., op. cit., p. 4, pl. 3, figs. 2, 2^a, 2^b; and *H. Stimpsoni* Ver., op. cit., p. 5, pl. 3, fig. 1, 1869, resemble this genus but probably belong to *Eloactis* Andres. No specimens of either species were preserved by Dr. Stimpson. His original drawings show no suckers.

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* Andres, in his classical work on the Actinaria, has entirely overlooked my two illustrated articles on Actinaria of the North Pacific Expl. Expedition, in the Comm. Essex Inst., vols. v and vi, 1868, 1869, quoted above, and has, therefore, omitted one of the above named species from his work, as well as numerous other species and several genera first described and illustrated in those papers. In several cases he stated that no figures nor descriptions of certain species therein described had been published. Nevertheless he quotes those papers in his bibliography. In the papers referred to there are four plates of Actiniæ (40 figures). He also failed to quote several other papers by me. Among those omitted are Report on Invert. of Vineyard Sound, etc., 1874; Radiata from Coast of North Carolina, this Journal, iii, p. 432, 1872; Bulletin, U. S. Nat. Mus., No. 15, 1879; American Naturalist, ii, p. 251, and several others. He intended to include all the literature and all known species. Such omissions are liable to happen in the best works.

H. producta ranges from S. Carolina to Cape Cod. *Var. albida*, Cape Cod.*

Eloactis brevicornis and *E. Capensis* are from Cape of Good Hope.

E. Stimpsoni, Hong Kong, China.

Family BUNODACTIDÆ Verrill = *Bunodidæ* Gosse.

Bunodactis V., new name = *Bunodes* Gosse (restr.)

Bunodes (*pars*) Gosse, 1855, 1860, *not* of Eich. (genus of Eurypteroidea), 1854.

Unfortunately the name *Bunodes* was preoccupied,† as indicated above, for a genus of eurypteroids, and some other name has to be chosen for this well known genus of actinians. None of the numerous groups recently established seem to correspond with this genus, and I have, therefore, given it a new name.

This genus, as now limited, includes species that have from 12 to 48 pairs of perfect mesenteries,‡ the number increasing with age. All the larger mesenteries, except the directives may bear gonads. The submarginal sphincter is prominent, endodermal and circumscribed. The verrucæ of the column are intraseptal evaginations of the wall and serve as true adhesive suckers; some of the rows may reach the base. The wall is imperforate, at least in the typical forms. The marginal tubercles are simple and similar to those below, and are not true acrorhagi, though sometimes pigmented distinctively. The wall is thick and muscular.

Bunodactis seems to include a considerable number of species, widely distributed. Among these are the following: *B. verrucosa* (Penn.) = *gemmacea* (type); *B. Balli* (Cocks); *B. Listeri* (Johns.); *B. glandulosa* (Otto) = *B. rigida* (And.); *B. thallia* (Gosse); *B. sabelloides* (Andres), all from European seas; *B. pluvia* (Dana); *B. cruentata* (Dana); *B. ocellata* (Less.), and *B. papillosa* (Less.), West S. America; *B. inornata* (Ver.) Hong Kong; and *B. Japonica* (Ver.) Japan. In accordance with the usual custom, the change in the typical generic name will make it necessary to change the family name *Bunodidæ* to *Bunodactidæ*. Tealiadæ (Hert.) might be used, were not *Tealia* a synonym of *Urticina* (Ehr., 1834, restricted).

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* Andres has based a new sp. (*H. Elizabethæ*) on an incorrect outline figure of this, in a popular work. It is the same as *H. albida*.

† Eichwald, Bull. Soc. Imp. Nat. de Moscou, vol. xxvii. part I, pp. 50, 107, pl. II, figs. 2–4, 1854, *Bunodes lunula*. The article is dated, at the end, Nov. 2,1853.

‡ Y. and A. F. Dixon (Sci. Proc. Roy. Dublin Acad., ii, p. 310) have shown that in *B. thallia* the number of mesenteries and their arrangement are remarkably variable, and that abnormal specimens are found with one or with three pairs of directives and corresponding siphonoglyphs. I have found the same variations in *B. stella*, which usually has about 24 pairs of perfect mesenteries.

Bunodactis stella Verrill.

Bunodes stella Verrill, Revis. Polyps E. coast of U. S, p. 16, pl. I, figs. 1–8, 1864; Amer. Naturalist, II, p. 258, 1868.

Bunodes spectabilis Verrill, Check List Mar. Invert. N. New Eng., p. 15, 1879; Cont. to Nat. Hist. of Arctic America, in Bulletin U. S. Nat. Mus., No. 15, p. 152, 1879 (*non* Fabr.).

Bunodes (?) *stella* Andres, Attinie Golfes von Neapel, p. 230, 1884. McMurrich, Actinaria of Bahama Is., p. 30, 1889.

Having received large specimens of this species from Greenland and Cumberland Gulf, I at one time identified it with *A. spectabilis* Fabr., owing mainly to the green color of the latter, but as this was not described as verrucose, it is more probable that it was the green variety of *Urticina crassicornis*, which also occurs in Greenland. At Eastport, Me., between tides, a common variety of the latter is green mottled more or less with red or brown.

This species is a true Bunodes, closely related to the common European species (*B. verrucosa*), as stated in my detailed description in 1864. It is somewhat singular that Andres, with my full description and figures, should have put it as a doubtful species, even suggesting that it might belong to *Aulactinia*, a genus established by myself for a species described in the same paper with the present one, as if I did not know the characters of my own genera and species!

McMurrich simply followed Andres in expressing this doubt, but regretted that he could not obtain examples for study, after futile efforts. It is, however, a very abundant species at low-water mark at Eastport, Me., and numerous specimens have been preserved by me for the Mus. Comp. Zool. (including the original types); the U. S. Nat. Mus.; the Mus. of Yale University, etc. He certainly did not ask me for specimens.

He also described a very different species, from the Bahamas, for which he proposed the provisional name of *Aulactinia stelloides*, but he, at the same time, expressed the opinion that it might prove to be identical with *B. stella*.

Mr. Duerden (Journ. Inst. Jam., ii, p. 454, 1898), misled by this statement, went farther and definitely united the same species, from Jamaica (as *Aulactinia stella*), with my *B. stella*. The latter is a very arctic littoral species, ranging from Maine to Greenland. Its occurrence as a littoral species in the West Indies would, of itself, be a case without parallel. The West Indian species probably belongs to a different genus, but it does not agree with the characters of typical *Aulactinia*.

For such species I propose the name *Bunodella*.

Bunodella V., gen. nov. Type *B. stelloides* (McMur.)

Form of body and tentacles same as in *Bunodactis*. Column with longitudinal rows of true adhesive verrucæ on the upper part. Margin with a row of simple, round or conical verrucæ similar in structure to the others. Mesenteries in several cycles with but six perfect pairs (in the type). Submarginal sphincter well developed, endodermal, circumscribed.

Differs from *Aulactinia* in not having lobate marginal verrucæ. The structure of the column-wall is also different: From *Bunodactis* it differs, so far as known, in having but six pairs of perfect mesenteries, as in very young examples of the latter. Should larger specimens of *Bunodella* be found to have a greater number of perfect mesenteries, this group would not differ essentially from *Bunodactis*.

Anthopleura Dowii Ver. **Figure** 8.

Trans. Conn. Acad. Sci., i, p. 474, 1869; Andres, op. cit., p. 223, 1884 (*Dovii*).

This species was pretty fully described by me in 1869, but the anatomy was not then given.

A medium sized example, 40^{mm} across, in alcohol, has about 96 pairs of mesenteries, of which 48 are perfect and furnished with large plicated muscles along most of their breadth; a pair of very small imperfect mesenteries, without gonads, usually intervenes between each perfect pair. The mouth has two large siphonoglyphs and about 22 crenulations on each side. Sphincter muscle well circumscribed, ovate in section, not very large. Larger submarginal tubercles or actinobranchs have 4 to 6 lobules on the lower side, each with a small point, appearing as if perforated, though the openings, said to exist in life, are not visible (fig. 8). Adhesive, cup-shaped suckers, of the longer rows, reach the base. Panama to San Salvador.

Anthopleura Stimpsoni Ver., Comm. Essex Inst., vi, p. 32, 1869. Figure 9.

This species has 12 pairs of perfect mesenteries, with large muscles along most of their breadth; 12 pairs of 3d cycle, well developed; about 24 pairs of 4th cycle, of small size and barren; all the others, except directives, bear large gonads. Sphincter muscle circumscribed, rather large, ovate in section. Actinobranchs (fig. 9) crowded, three to five in the larger rows, the upper one three to five lobed or digitate, the larger lobes often subacute and perforated. Adhesive suckers large, in unequal rows. Hong Kong, China. Type.

Bunodosoma, gen. nov. Type, *B. granulifera* (Les.).

General form and appearance as in *Bunodactis*, but the hollow verrucæ, arranged in vertical rows, are rounded or subconical and do not form adhesive suckers. Upper or submarginal ones are larger and in mature specimens more or less lobulated, but have nearly the same structure as those below, though they are described as perforated when living. Tentacles numerous; many mesenteries, 12, 24, or more pairs being perfect. Sphincter muscle well developed, endodermal and circumscribed.

To this group I refer the following:

Bunodosoma granulifera (Les., 1817).

Aulactinia granulifera Andres, 1884, p. 221.
Bunodes granulifera Duerden. 1898, p. 454.
Bunodes tæniatus Mc Mur., 1889, p. 23.
Cereus Lessoni Duch. and Mich., 1860, p. 42.

West Indies.

Bunodosoma cavernata (Bosc, 1801).

Bunodes cavernata Ver., 1864, p. 17.
Cladactis cavernata Ver., 1869, p. 473.
Phymactis cavernata Andres, 1884, p. 231; Mc Mur., 1887, p. 51.

South Carolina to Cape Hatteras.

Various other species described under *Bunodes*, *Aulactinia*, etc., may belong here, but the descriptions of the verrucæ and other parts are insufficient to determine their position. *Aulactinia crassa* Andres looks more like *Bunodosoma* than like *Aulactinia*.

Family PHYLLACTIDÆ.

Asteractis Verrill, 1869. Type, *A. Bradleyi*.

Asteractis Verrill, Trans. Conn. Acad. Sci., i, p. 465, 1869. Andres, op. cit., p. 292, 1884.

This genus is characterized by the presence of a special wide ruffled collar outside the tentacles, covered with complex rows of compound verrucæ or lobed outgrowths,* but not forming true free fronds. The column bears more or less numerous adhesive verrucæ in rows below the collar. There are 12 or 24, or more pairs of perfect mesenteries and one, or sometimes two, endodermal sphincter muscles.

Asteractis flosculifera (Les.) Ver.

Actinia flosculifera Les., Journ. Acad. Sci. Philad., i, p. 174, 1817 (not *Oulactis flosculifera* Duch. and Mich., nor of McMurrich).
Evactis (?) *flosculifera* Andres, op. cit., p. 235.
Oulactis fasciculata McMurrich, Proc. Philad. Acad. Sci., 1889, p. 108; also in Heilprin's "The Bermuda Islands," p. 112, pl. x, fig. 5 (section), 1889.

This species is common at Bermuda, living buried to its margin in shell-sand at low-water mark. Figures from life will be published soon in Trans. Conn. Acad. Science.

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* They are probably branchial in function and may be called actinobranchs (*Actinobranchiæ*). The groups that they form may be called pseudofronds.

It has been pretty fully described, as to its anatomy, by McMurrich. The collar is covered by radial pseudofronds composed of about three rows each, of lobed tubercles, the lobules being short or rounded; a single larger lobed tubercle or actinobranch occupies the distal end of each group, and a nearly simple one often forms the proximal end, next to the fosse at the bases of the tentacles. The color is variable, but the collar is usually umber-brown, varied with yellowish, flake white, and reddish brown spots.

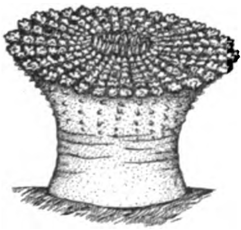
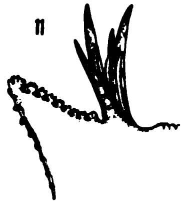


Fig. 10.

Asteractis Bradleyi Ver. Figures 10, 11, 12.

Trans. Conn. Acad., i, p. 465, 1869. Andres, op. cit., p. 292, 1884.

This is closely allied to the preceding species. The pseudofronds of the collar are made up of more finely lobulated verrucæ, so that they appear more complex. These verrucæ, in the alcoholic specimen, are closely crowded in each radial series, of which there are 48; their upper and lateral surfaces are divided into many small rounded or conical lobules, most prominent along the outer sides and at the distal end of the last or distal one, where about five lobules project, in each group, beyond the edge of the collar, giving it a finely serrate or fringed appearance (figs. 11, 12). The verruciform adhesive suckers are in 48 rows, of 3 to 5 each, corresponding to the



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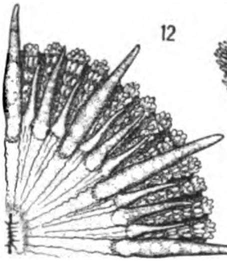

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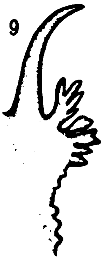

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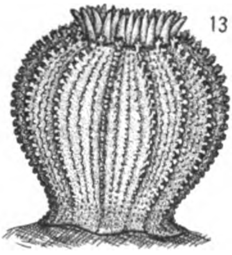

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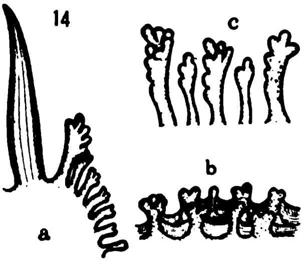

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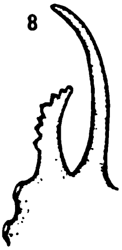

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pseudofronds, and extending only a short distance below the collar.

The general figure, now given, is based on a sketch from life, by F. H. Bradley, of the original type, corrected by comparison with the preserved specimen, which was from Panama.

Asteractis conquilega (Duch. and Mich.) Ver,

Oulactis flosculifera Duch. and Mich., Corall. Antill., p. 46, 1860 (*non* Les.); Supl., p. 129, 1866. McMurrich, Actin. Bahamas, p. 56, pl. II, fig. 2, pl. IV, figs. 12-14 (anatomy). 1889.

Oulactis conquilega Duch. and Mich., op. cit., pp. 49, 89, pl. VII, figs. 7, 11, 1860.

Oulactis foliosa Andres, op. cit., p. 290, 1884.

The collar of this West Indian species is very broad and is covered with about 24 pseudofronds, or groups of small folds and lobulated and crowded actinobranchs, much more complex than in either of the preceding species.

Asteractis formosa (Duch. and Mich.) Ver.

Oulactis formosa D. and M., op. cit., p. 47, pl. VII, figs. 4, 5, 1860; Supl., p. 36 (130), 1866. Andres, op. cit., p. 291.

This is closely allied to the preceding species, but has smaller and less complex groups of lobulated actinobranchs on the collar and fewer tentacles. Guadaloupe.

Family DENDROMELIDÆ McMurrich.

Lebrunia Duch. and Mich., Corall. Ant., p. 48, 1860.

Actinodactylus (*pars*) Duch. and Mich., op. cit., p. 44, 1860.

Stauractis (*pars*) Andres, op. cit., p. 255, 1884 (new name for last).

Taractea Andres, op. cit. p. 284, 1884 (for *L. Danæ*).

Lebrunea McMurrich, Actinaria Bahama Is., p. 33, 1889; Duerden, Actin. Jamaica, p. 456, 1898.

This remarkable genus is characterized by having a series of about six (sometimes 5 or 8) large, dichotomously branched fronds, or branchiæ (*actinobranchiæ*) exterior to the tentacles. The species examined by me has, on these fronds, at the forks, many more or less spherical bodies having the structure of acrorhagi. There are numerous mesenteries, most of them perfect and bearing gonads. Sphincter muscle feebly developed or wanting.

The genus *Actinodactylus* Duch., 1850, was based on *A. Boscii* D., which may, perhaps, have been only a young *Lebrunia*. It was only 4 to 5 lines in diameter, with 15 small, simple tentacles, in a single circle, and with 5 elongated, pedicelled, trilobed fronds, the lobes with small subdivisions. It may, however, prove to be a distinct genus when larger examples can be studied.

The second species referred to it (1860), as *A. neglectus*, appears to be the young of *Lebrunia neglecta*, described in the same work. Although it was only 5 lines in diameter it had 30 tentacles and 5 dichotomously branched fronds.

Lebrunia Danæ (D. and M.) Verrill. Figure 15.

Oulactis Danæ Duch. and Mich., op. cit., p. 47, pl. VII, fig. 10 (frond), 1860.
Rhodactis Danæ Duch. and Mich., Supl., p. 37, 1866.
Taractea Danæ Andres, op. cit., p. 284, 1884.
Lebrunea neglecta Duerden, Actin. Jamaica, p. 456, 1898.
? *Hoplophoria coralligens* Duerden, loc. cit. (*non* Wilson).*

Specimens of large size, up to 8 inches or more in diameter, were obtained by me at Bermuda, in 1898. These agree very well with the specimens described by Duerden from Jamaica, as *L. neglecta*, but not with those described by McMurrich under the same name. In having numerous rounded acrorhagi on the actinobranchs or fronds (fig. 15) my species agrees with the *Oulactis Danæ* D. and M., from St. Thomas, which is evidently a *Lebrunia*, and there is no reason to doubt its identity with the Bermuda species.

My larger examples were usually dark green in life, with the tentacles somewhat paler green and flecked more or less with white; disk olive-green with whitish radial spots; fronds bluish green with the tips and rounded bodies light blue. It lives with the body concealed in holes or crevices of the reef-rock, at and below low-water mark. The tentacles are long.

Lebrunia neglecta Duch. and Mich.

Lebrunia neglecta Duch. and Mich., op. cit., p. 48, pl. VII, fig. 8, 1860 (young). Andres, op. cit., p. 362 (*non* Duerden).
? *Actinodactylus neglectus* Duch. and Mich., op. cit., p. 44, 1860 (very young).
? *Stauractis incerta* Andres. op. cit., p. 255, 1884 (new name for last).
Lebrunea neglecta McMurrich, Actin. Bahama Is., p. 33, pl. I, fig. 7 (general), pl. III, figs. 11–14 (anatomy).

This species was originally based on a small specimen (about one-half an inch high), but it had relatively large, much dichotomously divided fronds, according to the figure. McMurrich has given a detailed description of a species that appears to be the same, though much larger in size. His figures represent the 6 fronds as dichotomous, but with few divisions, though in his description it is stated that they "dichotomize many times until a dendritic structure is produced." The rounded bodies are not figured nor described by him, nor by D. and M. as occurring on the fronds. In this respect the fronds are very different from those of the Bermuda species studied by me. I am, therefore, disposed to believe that there are two large West Indian species.

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* The *Hoplophoria coralligens* Wilson, was described from a single, very small specimen (diameter about 2^{mm}), having 48 unequal tentacles and 4 simple, elongated, marginal fronds. Duerden identified with it a small form of *Lebrunia*, having dichotomous fronds and agreeing nearly in color, etc., with *L. Danæ*. The identity of his specimens with the true *Hoplophoria* seems to me very doubtful. This generic name is unfortunate for its variants, *Hoplophorus* and *Hopliphorus*, had been used previously for five distinct genera. It evidently cannot be the young of either nominal species of *Actinodactylus*, for although much smaller, it has more tentacles. It is most likely to be the young of *Diplactis Bermudensis* McMur., or some similar species.

Subfamily ALICIINÆ = Family ALICIADÆ Duerden.

Duerden, Ann. and Mag. Nat. Hist., 6, xv, p. 213, 1895; Haddon and Duerden, Sci. Trans. Roy. Dublin Soc., vi, p. 153, 1896.

This family was established to include certain tuberculated genera, such as *Alicia* (= *Cladactis* Panc.), *Cystiactis*, etc.

It is characterized by a thin wall; feeble, diffused sphincter muscle; hollow tubercles, usually compound, on the column; 12, 24, or more pairs of perfect mesenteries; no acontia.

The wall-tubercles are thin and doubtless serve as branchiæ; they are not adhesive suckers.

The group is practically equivalent to tuberculated *Actinidæ*, and might well form a subfamily of that family.

Eucladactis Ver., new name. Type, *E. grandis* V.

Cladactis Ver., Trans. Conn. Acad. Sci., i, p. 472, 1869 (*non* Panceri, 1868).

By a mere coincidence the name *Cladactis* was given by M. Panceri and myself to two distinct genera, at nearly the same time. The former appears to be the same as *Alicia* Johns. which preceded it. No other name seems to have been given, as yet, to my *Cladactis*. The latter is characterized by very numerous tentacles, which are scarcely retractile; column thickly covered with hollow clavate and lobulated tubercles, the upper ones larger and more lobed than the rest; margin with a deep fosse; sphincter muscle very feeble and diffuse, or almost lacking; 36, 48, or more pairs of perfect and many imperfect mesenteries, having feeble muscles extending along most of their breadth; gonads numerous, borne on most of the mesenteries, both perfect and imperfect; a distal septal foramen; mouth large, with two large equal siphonoglyphs; lips with very numerous lateral furrows.

Eucladactis grandis Ver. Figures 13, 14.

Cladactis grandis Ver., Trans. Conn. Acad. Sci., i, p. 473, 1867. Andres, op. cit., p. 226, 1884.

The larger specimens of this species are over 2 inches in diameter and height, as preserved in alcohol. The tentacles are partially contracted in length and sulcated, but are rarely concealed, even in the young, by the infolding of the margin of the disk; generally they are fully exposed and the margin is but little contracted or not at all, owing to the feeble development of the circular muscles. There are about 480 tentacles in the larger specimens; they form five or six crowded rows, the inner ones standing about half way between the center and the margin of the disk; the inner ones are larger and somewhat swollen at the bases but are not much longer than the outer ones; all are sulcated by contraction. The lips have about 48 to 60 furrows on each side. The mesenteries are hexamerous and, like the tentacles, vary in number according to the age. A medium-sized specimen had about 120 pairs, of which about 48 were perfect, but the arrangement is more or less irregular, for one, two, or even three imperfect pairs may intervene between the various perfect pairs. The larger specimens have about 60 pairs perfect and about 180 imperfect. Nearly all bear gonads. The larger upper actinobranchs (fig. 14 *a*, *c*), next the smooth fosse, are elongated, more or less clavate, the distal portion divided into four to six irregular rounded or obtuse lobules; those lower down become shorter and less lobulated, but nearly all are clavate or capitate, to the base, and most of them, in large specimens, are divided into two, three, or more lobules. They are thickly crowded over the whole surface, and in alcoholic specimens appear to be united together in horizontal series by thin folds of the wall (fig. 14 *b*).

Panama; Paita, Peru; San Salvador.

Explanation of figures.

Fig. 7. *Haloclava producta* (St.). Type, natural size.

Fig. 8. *Anthopleura Dowii* V. Side view of a tentacle, actinobranch, and two upper verrucæ. Enlarged.

Fig. 9. A similar view of the same organs of *Anthopleura Stimpsoni* V., from the type, enlarged.

Fig. 10. *Asteractis Bradleyi* V. Type, about natural size.

Fig. 11. The same, side view of tentacles and actinobranchs.

Fig. 12. The same, view of a portion of the disk, tentacles, pseudofronds, enlarged.

Fig. 13. *Eucladactis grandis* Ver. Type, ½ natural size.

Fig. 14. The same; *a*, one tentacle and a single vertical row of actinobranchs; *b*, a group of actinobranchs or papillæ from the middle of the column; *c*, various forms of marginal actinobranchs.

Fig. 15. *Lebrunia Danæ*, one of the actinobranchs with acrorhagi, ½ natural size.

Figs. 8 to 15 are by A. H. Verrill. Fig. 7 is by Wm. Stimpson.

Erratum—In part I, p. 494, line 17, for W. E. Coe, read W. R. Coe.

ART. VII.—*Mineralogical Notes: Analyses of Tysonite, Bastnäsite, Prosopite, Jeffersonite, Covellite, etc.;* by W. F. HILLEBRAND.

IN the following pages are given the results of several analyses of minerals made in the laboratory of the U. S. Geological Survey during the past few years. In the cases of tysonite and bastnäsite the results show that the formulas attributed to them are correct, which in the absence of fluorine determinations could not hitherto be affirmed. In the other cases the analyses are interesting only as affording additional data regarding rare minerals from new localities.

Tysonite and Bastnäsite.

These minerals formed a single fine specimen half as large as the fist, without crystal faces, from Cheyenne Mountain, near Pike's Peak, Colorado. The bastnäsite covered one side of the tysonite to the depth of an inch. The line of demarcation between the two minerals was sharp, but examination of their sections by Mr. H. W. Turner showed the tysonite to be permeated by stringers of bastnäsite along numerous cracks and that occasional grains of the latter were imbedded in the tysonite, which accounts for the CO_2 shown in the tysonite analysis. Attached to the tysonite at portions of its surface were other white and brownish alteration products derived from it, as shown by qualitative tests. The tysonite was evidently the remnant of a single large crystal, since, according to Mr. Turner, all parts had the same optical orientation. Mr. Turner further found the optical properties of both minerals, so far as determinable, to agree with those given in Dana's Mineralogy, and the index of refraction of the bastnäsite to be greater than that of the tysonite. He likewise noted in both minerals minute colored inclusions, indeterminable and very trifling in amount, and also in the tysonite "numerous minute angular cavities in which there is a liquid, often with gas bubble. Minute, clear, cuboidal crystals, apparently isometric, were also noted in some of these cavities."

The composition of the minerals was found to be as given by Allen and Comstock, with the exception that the ratios of cerium oxide to the oxides of the lanthanum group are not quite the same. The formulas are not thereby affected.

Cerium was separated from the lanthanum group oxides by two precipitations by potassium hydroxide followed by long introduction of chlorine. After recovery of the earths remaining in solution, they were again subjected to this treatment to be certain of having all the cerium. In one case a small portion was thus recovered. The cerium was most carefully examined for thorium and traces of what appeared to be thoria were found. The other earths were wholly precipitable by potassium sulphate with exception of traces of what may be oxides of the yttrium group. Approximate molecular weight determinations of the combined oxides of these two groups were made, and they show an appreciable difference, which may, however, be due to the uncertainty of the method. It may be mentioned that on ignition of the sulphates of these earths they acted like the old didymium in that they lost exactly two-thirds of their SO_3 on ignition over the full flame of the Bunsen burner, a fact which would seem to exclude the presence of lanthanum. Their solutions were pink and gave pronounced absorption spectra. The ignited oxides freed from cerium were a dull dirty brown, which became nearly white on blasting and acquired a distinct bluish cast on ignition in hydrogen. No appreciable reduction in weight followed heating in hydrogen. The material saved is at the disposal of any one desiring to examine these earths spectroscopically.

Owing to the great difficulty in effecting complete decomposition of the minerals by sulphuric acid at a single treatment, the fluorine was obtained in condition for estimation by fusing with potassium carbonate after mixing with silica in the proportion of 0·6 gram mineral to 1 gram silica.

Fragments of tysonite when held in the blast gave a distinct crimson flame showing the lithium red line, but an alkali determination failed to reveal more than a trace of this element.

Of the bastnäsite very little pure material could be separated, and it was therefore impossible to place with certainty all the loss shown by the analysis, but a portion of it is to be charged to the oxides of the lanthanum group because of an accident.

Sp. grav. of the bastnäsite 5·12 at 27° C. and of the tysonite 6·10 at 28° C., which becomes 6·14 when corrected for 2·65 per cent of bastnäsite.

Analysis of Tysonite.

Ce_2O_3	42·89*
La group	39·31†
F	28·71‡
CO_2	·53
CaO	·18
Fe_2O_3	·11
Na_2O§	·30 (approx.)
	112·03
Less O for F,	12·08
	99·95

* 13 per cent ThO_2?

† At. w. 139·7; includes ·21 per cent soluble in K_2SO_4.

‡ Mean of 28·86 and 28·56.

§ With traces of K and Li.

Analysis of Bastnäsite.

Ce_2O_3	37·71*
La group	36·29† (low)
F	7·83
CO_2	20·03‡
Fe_2O_3	·22
Na_2O§	·18
H_2O	·08
	102·34
Less O for F	3·30
	99·04

* Mean of 37·73 and 37·69; includes ·10 per cent ThO_2?

† At. w. 141; includes ·09 per cent soluble in K_2SO_4.

‡ Mean of 19·94 and 20·11.

§ With traces of K and Li.

Neglecting the three last constituents in each case, the ratios become for

Bastnäsite.... $R : F, CO_3 = 1 : 2·94$
Tysonite..... $R : F, CO_3 = 1 : 3·05$

which ratio for tysonite is not changed by allowing for admixed bastnäsite.

The above direct fluorine determinations fully establish the hitherto assumed formulas, $R'''F_3'$ for tysonite and $R'''(F,'CO_3'')$ for bastnäsite.

Prosopite.

Over two years ago Mr. Geo. F. Kunz sent for examination a beautiful pale green mineral from Utah, supposed to be identical with the green variscite called by him utahlite in Mineral Resources of the U. S., 1894, p. 602. Under a recent date Mr. Kunz writes that Mr. T. H. Beck of Provo found the mineral "in 1895, in the Dugway mining district, Torvel Co. It was found in a low range of hills about five miles long, surrounded by a desert on an arid region occurring as flat rock, associated with fluorite, native silver and slate, and trachytic rock (?), containing decomposed pyrite in which there was present a little free gold."

Unexpectedly this was found to be the hydrous aluminum-calcium fluoride prosopite, mixed with some quartz and probably fluorite and colored by a small amount of some copper salt. A new and interesting occurrence for this very rare mineral is thus afforded.

The material as prepared for analysis after separation by a heavy solution proved to be still far from pure; quartz grains in amount from one to two per cent were left undissolved after complete conversion of the fluorides into sulphates and presumably considerably more had been removed by the escaping fluorine. The total amount of quartz was not determined and the material at hand did not suffice for attempts at more complete purification, so that the conclusions drawn from the analysis, while extremely probable, are not to be taken as altogether proven.

The sp. gr. of the mineral as analyzed was 2·87 at 21° C. and the hardness about 4·5, both agreeing with the constants for prosopite. Furthermore, but little of the water (1·25 per cent) was expelled by several hours heating at 280° C. Analysis gave:

Al	20·08
Ca	17·55
Mg	trace
K	·12
Na	·32
Cu	·17
F	28·00
H_2O	14·24
Quartz and oxygen	19·52
	100·00

Neglecting copper, alkalies, and the oxygen calculated for their oxides, and assuming the water to exist entirely as hydroxyl, the following not very satisfactory atomic ratios result:

Al	·7407	2
Ca	·4380	1·18
F	1·4690	8·23
Hydroxyl	1·5808	

which become

Al	·7407	2
Ca	·3712	1
F	1·3354	7·87
Hydroxyl	1·5808	

if enough calcium and its equivalent in fluorine are subtracted to make the ratio Al : Ca exactly 2 : 1, on the not improbable assumption that fluorite is present as an admixture, an assumption that had to be made also for the Colorado prosopite in order to bring it into close agreement with Brandl's formula.

There is now a deficiency in the acidic radicals. The figures for Al, Ca, and H_2O are undoubtedly very nearly correct while the fluorine may well be half a per cent low, having been determined by the Berzelian method, owing to the difficulty of securing complete decomposition of the fine powder by a single treatment with sulphuric acid. Let it be permitted to balance the basic and acidic radicals by raising the fluorine, and to figure the ideal percentages on this basis. These become of interest when compared with the corresponding figures for prosopite from Altenberg and Pike's Peak as given below:

	Altenberg.	Pike's Peak.	Utah.
Al	23·37	22·02	22·74
Ca	16·19	17·28	16·85
F	35·01	33·18	29·95
H_2O	12·41	13·46	16·12
O	12·58	13·41	14·34
			100·00

If the assumptions made in the foregoing are justified, the Utah mineral is prosopite, and further evidence is afforded of the correctness of the view established by Penfield that fluorine and hydroxyl can mutually replace one another in many mineral species, for their relative proportions differ materially in the prosopite from the three known localities. The correctness of the formula as applied to the Colorado and Utah prosopite is, however, predicated, as said, on the unproven assumption that the material analyzed contains some admixed fluorite.

Jeffersonite.

Two brown substances associated with franklinite and other zinc minerals from Franklin Furnace, N. J., so alike in appearance as to have been taken for the same mineral species, were received from Mr. Geo. L. English. One was a little duller than the other and proved to be a mixture of several minerals according to Mr. F. L. Ransome of the Geological Survey, largely pseudomorphic after some micaceous mineral. From Prof. Clarke's calculations, based on the following analysis, it might be a mixture of a calcium-aluminum garnet, troostite, and limonite. SiO_2 32·09, Al_2O_3 11·12, Fe_2O_3 5·16, MnO 15·85, ZnO 16·89, CaO 15·65, H_2O 2·15, MgO and alk 1·12; total 100·00.

The other was of a richer and deeper brown and showed such a pronounced cleavage or parting in one direction as to produce a lamellar structure. The luster was brilliant on these cleavage surfaces. Other directions of cleavage were apparent. The hardness was about 5·5 and the density 3·39 at 21·5° C. Before the blowpipe a fragment fused with difficulty to a light colored blebby glass. Analysis gave:

SiO_2	51·70
Al_2O_3	·36
Fe_2O_3	·37
MnO	7·43
ZnO	3·31
CaO	23·68
MgO	12·57
Na_2O	·12
K_2O	trace
H_2O	·65
	100·19

TiO_2, FeO, P_2O_5 absent.

Neglecting the sesquioxides, alkalies and water, this leads to the ratio $SiO_2 : RO = 1 : 1·02$, and the formula is that of a metasilicate $R''SiO_3$. According to Mr. English the material submitted by him had been pronounced by Prof. Penfield on the basis of qualitative tests to be jeffersonite, a manganese-zinc pyroxene, a statement supported by the analysis above given, although neither the color of the mineral nor its quantitative composition agree with the hitherto published data. In Dana's Mineralogy the color is given as "greenish black, on the exposed surface chocolate brown," the density as 3·36 on p. 358, but 3·63 on p. 360. The discoverers of the species, Keating and Vanuxem, give 3·50–3·55 for the density and 4·5 for the hardness. The present mineral presents all the evidences of being fresh and unaltered, yet it is brown throughout, and its analysis furnishes figures widely at variance with those of Herrmann and of Pisani, but giving a better metasilicate ratio than either of their analyses. Notwithstanding these discrepancies, there is no reason for ascribing to the mineral a new sub species name. The analysis is chiefly valuable as showing a wide range of composition for the mineral.

Covellite, Enargite, Stalactite.

The only important occurrence of covellite in this country is at Butte, Montana, where it occurs in splendid indigo-blue masses. Specimens from the East Greyrock mine, collected by Mr. Geo. W. Tower of the Geological Survey, gave almost the theoretical composition as shown below. Sp. gr. at 26° C. 4·76, uncorrected for impurities.

An analysis of enargite collected by Mr. Tower in the Rarus mine, and of a beautiful sky-blue stalactite from the Anaconda mine, both at Butte, are likewise given.

Covellite.	
Cu	66·06
S	33·87
Fe	·14 = ·30 FeS_2
Insol.	·11
	100·18

Ratio Cu : S as 1 : 1·01

Enargite.	
Cu	48·67
Fe	·33
Zn	·10
As	17·91
Sb	1·76
S	31·44
Insol.	·11
	100·32

Stalactite.	
CuO	9·32
FeO	·18
MgO	·08
Al_2O_3	10·67
SO_3	35·05
P_2O_5	1·13
As_2O_5	·07
H_2O	43·44
Insol.	·06
	100·00

The stalactite was of some size, and was most readily soluble in cold water, the solution giving a strong acid reaction. The calculated ratio is strongly acid, showing either a mixture of highly acid salts or of normal salts with free acids.

Fibrous sulphate.

Mr. W. H. Weed collected in the St. Paul mine, near Whitehall, Montana, a magnificent specimen of a compact soluble fibrous sulphate, supposed to be melanterite. It seemed to be a filling between fragments of broken rock. Outwardly it was white from dehydration, but at some depth the unaltered green mineral was to be found. This had the following composition:

Al_2O_3	4·34
FeO	9·04
NiO	·03
MnO	2·62
ZnO	1·06
CuO	·05
CaO	·09
MgO	3·07
Na_2O	·07 ?
SO_3	29·88
Cl, CO_2	none
H_2O	48·84
Insol.	·16
	99·25

Of the water 10 per cent escaped in 24 hours over sulphuric acid and only ·4 per cent more in another like period, but a total of 14·4 per cent after 10 days uninterrupted exposure. The water thus lost is very slightly reabsorbed on exposure to air.

From calculations by Prof. F. W. Clarke the substance may be regarded as a mixture of alunogen or the halotrichite group with salts of the melanterite group, the empirical formula being nearly

$$(Fe, Mn)_4(Zn, Mg)_2Al_2(SO_4)_9 . 65H_2O.$$

The outer white zone of the specimen contained only 39·62 per cent of water.

Laboratory of the U. S. Geological Survey, July.

ART. VIII.—*What is the Loess?* by F. W. SARDESON.

THERE is wide difference of opinion regarding the origin of the American loess. Is it an aqueous or an æolian deposit? Many believe it to be partly aqueous, partly æolian, and thereby raise the very important question of how to distinguish the one kind of loess from the other. To those who view the loess as æolian, this discrimination is easy, for the loess is all æolian except locally where distinct sedimentary characters appear. The loess is interpreted by them as wind-carried dust, deposited on a land surface interrupted by streams and ponds.

The loess viewed as a sediment is also easily distinguishable from other sediments, but requires then the very difficult explanation of how a little altered glacial sediment could be so peculiar,—in fact like dust deposit. Negative evidence to this theory is found in a region like Minnesota, where there are thousands of existing and extinct lakes of glacial origin, in not one of which is loess known to have deposited,—not even in Lake Agassiz. They have in them gravels, sand and silt, and around them are beaches. No small nor shallow lake could have spread over the extremes of altitude on which the loess lies, and a necessarily huge body of water must have left some beaches and coarse sediments besides silt or loess. It was not a lake that deposited the loess. The loess could also scarcely be all a glacial sheet flood deposit. For example, the Iowan loess lies beyond the Iowan drift sheet as it were its continuation. Either the loess is the older and hence remains intact only beyond the Iowan glacier's domain, or else the loess is contemporaneous and deposited by agency of the same glacier's waters. The latter is the sedimentary theory. But the theory does not explain why the glacial waters ceased depositing loess when the glacial retreat began. Iowan loess does not cover the Iowan drift,* and this fact the æolian theory alone can explain. Partial or entire recognition of the æolian origin is necessary.

Partial recognition does not, however, remove all inconsistencies, because "no means of discriminating between the two kinds of loess are yet known to be formulated,"† as the advocates of the mixed hypothesis‡ say. Prof. T. C. Chamberlin teaches this double origin of the loess, and his view, as understood by the writer, is that the glacial waters flooded sediments upon the land, and these were in part modified by æolian agent into "bluff loess."

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* Prof. S. Calvin discredits the reported slight occurrence of this loess on the Iowan drift. Iowa Geol. Sur., vol. viii, p. 174; see also p. 339.

† C. R. Keyes, this Journal, vol. vi, p. 229.

‡ T. C. Chamberlin, Jour. Geol., vol. v, p. 795.

In theory, the Chamberlin view may be essentially correct. The loess particles came from the drift, and very probably from washed drift largely. If the theory be applied, it should bring into recognition the following kinds and relations of deposits: the unassorted glacial deposit, or till; this, when assorted by agency of water, becomes stratified gravel, sand and silt; the two latter may be made by æolian agent into dune sand and "bluff" loess; and they, after erosion, may become again respectively stratified sand and silt; under the action of humic acids the silt of both kinds may be reduced to a loam in which there is no lime; and likewise the "bluff" loess may be reduced entirely, or to a degree, to "loess" loam. The till is easily recognized, as are also the stratified products, the gravels and sands. Dune sand lacks the assorted and stratified structure, and is easily distinguishable from the sedimentary patches associated with or in it. It seems strange, therefore, that silt and æolian deposit,—that is mud and dust,—should not be distinguishable.

Indeed, it is not difficult to discriminate between glacial silt and loess, and I believe that they are rarely if ever confused by geologists. The difficulty lies in the discrimination of theoretical sedimentary loess and æolian loess. There *are* two kinds of loess in the Mississippi basin, and they are distinguishable at a glance, but as said, they have not been proved separable on the basis of sedimentary and æolian origin. The two kinds are very intimately associated. They are respectively the characteristic calcareous, porous, "bluff" loess and the oxidized portion of the same, which may be called loess loam, residuary loess, or ferretto. Difference in color, or the application of hydrochloric acid, serves as a ready test of them.* Chamberlin and Salisbury, in their monograph, recognized the loess loam of the "Driftless Area" as residuary clay although they failed to connect it with the loess, as I have once before indicated,† and in fact Chamberlin has practically admitted the emendation by criticising other parts only of my paper.‡ The loess loam being due to oxidation by humic acids, its depth is determined by the vegetation upon its surface and by the time that this agent has acted, provided that the loess be not too shallow and surface erosion does not equal or exceed the rate of oxidation. On the Missouri and Mississippi River bluffs, the loess was originally deepest; it is also little covered with vegetation and highly exposed to erosion. On the higher but more level land farther from the great rivers, the loess was thinner and was also more oxidized. Often it is all oxidized.

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*This distinction is not new, for example see Geologischer Fuchrer d. Umgebung v. Freiburg, p. 78, Steinmann u. Graeff, 1890.

† Am. Geol., vol. xx, No. 6.

‡ Jour. Geol., vol. v, No. 6.

From my own observations compared with published descriptions, I feel safe in saying that, as a rule, the loess loam is what has been called sedimentary loess. If it *were* such, why is it not calcareous as are the known glacial silts? And if the "bluff" loess is derived from it, why is the former calcareous, since the latter is not? There is no explanation.

The above criticism applies to the loess as a rock type, but when the Loess formation is considered another distinction should be admitted, namely that there are two distinct loess formations, as H. F. Bain describes in northwestern Iowa,* which are comparable to the older and younger loess of the Rhine Valley. Each may bear loam.

The loess as a formation bears loam both upon and within. Upon the loess, the loam represents the portion which has been oxidized since the loess formation was deposited, while in the same it indicates patches of vegetation that were contemporaneous with the deposition. The loess loam, in combination with land and fresh water shells, forms the very strong argument in favor of the purely æolian origin of the loess. The æolian hypothesis is the one which permits the several parts of the loess to be both readily interpreted and easily recognized in the field, and it has therefore a distinct advantage over the semi-æolian hypothesis. It is further competent to explain without inconsistency the dune sands on the river bluffs and their graduation into the loess; wind polished pebbles lying between till and loess are recognized; two kinds of stratified silts existing with the loess or graduating into it are identified as respectively glacial silt from which the loess seems to have been largely derived, and modified or washed loess. Banded structure in the loess,† which is not true stratification, indicates the line of a moist zone where vegetation thrived and oxidized the loess. Dry runs and very probably rodent burrows and mounds can be easily recognized; and the occurrence of land and fresh water shells is not anomalous. Finally, when it is observed that much loess accumulated before one glacial period or ice advance and little before another, the same is consistently attributed to climatic conditions, to which kind of cause the glaciers themselves are referred.

University of Minnesota, Minneapolis.

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* Iowa Geol. Sur., vol. viii, p. 240.

† See for example, fig. 32, p. 235, vol. vii, Iowa Geol. Sur.

Art. IX.—*Absorption of Gases in a High Vacuum;* by C. C. Hutchins.

The term "absorption" is here used to cover the general phenomenon of the disappearance of the residual gas in a high vacuum under the electric discharge, whatever may be the cause of the disappearance.

It is well known to all users of X-ray apparatus that under the discharge from an induction coil the tubes rapidly rise in vacuum, and the current, after a longer or shorter time, ceases to pass, and the usefulness of the tube is at an end. This rise in vacuum constitutes the most serious defect in such tubes and is a source of constant annoyance.

It is probably safe to reject the theory that the electromotive force drives the molecules of the residual gas through the walls of the glass. It is possible to have an opening into a highly exhausted tube without the entrance of air.

This laboratory has for twenty years possessed a Crookes radiometer that has during all that time been cracked entirely around near the top of the bulb, but which, notwithstanding, continues to function perfectly. We also had for several months an X-ray tube similarly cracked. By constant use this tube became so high in vacuum that it was punctured by a spark; air entered and the cracked end fell away of its own weight.

The disappearance of the gas is therefore probably due to mechanical and chemical combination with the metallic electrodes of the tube, and it should be possible to find some gas or vapor whose rate of absorption would be less in rate or extent than that which takes place in the ordinary tubes.

The first step in the inquiry is to learn what the ordinary high-vacuum tube contains.

If a Plücker tube, made from carefully cleaned glass, be very highly exhausted and then the current from an induction coil turned into it, the vacuum falls at once, air and water being driven from the walls of the tube. If now by heating the tube, continuing the current and working the pump, the vacuum be again raised to the point at which the fluorescence of the glass appears, the spectrum of the tube will be found to consist of the red and blue lines of hydrogen (C and F), and three or four lines of oxygen; that is, the tube contains only water. The tenacity with which glass retains water upon its surface is well known; and it is necessary to heat the glass nearly to its softening point before the last of the water comes away. When the vacuum in a tube is so high that the current will not pass, heating the tube will dislodge a little water and the current will pass until the water has again condensed upon the cooling of the tube.

As the following experiments had for their object the production of a permanent state of vacuum under the electric discharge, they were limited to such gases as could be produced readily in the tubes themselves, and whose use seemed to hold out promise of success.

A number of Plücker tubes were made, as nearly alike as possible, and each provided with a small communicating tube containing some chemical that would yield the desired gas by the application of heat. The chemicals were prepared as pure as possible, and dried at a hundred degrees for twenty-four hours. The dried-out tubes, containing the chemicals, were then attached to the mercury pump and exhausted; heated very hot and pumped to remove all water vapor. The tube containing the chemical was then heated, gas driven off into the tube and the exhaustion repeated.

In nearly every case it was found impossible to entirely get rid of water vapor, even by repeatedly washing out with the gas. The tubes were sealed at such a degree of exhaustion as would allow the subsequent rise in vacuum to be well marked,—when the green fluorescence of the glass appeared at the cathode, and the sparking distance across the terminals of the coil and in parallel with the tube was 2^{mm}. After the tube was sealed, it was placed before a spectroscope, and the current from the coil passed until the spectroscope showed the entire absorption of the gas, or until the vacuum became too high for the current to pass readily. A fairly good idea of the relative rates of absorption of the various gases may be obtained from the time required for the absorption to take place.

Tube containing zinc cyanide.—This substance yields cyanogen when heated. The tube was washed out with the gas as above described and sealed. The vacuum began to rise at once as soon as the current was turned on. In five minutes the whole tube became fluorescent, and in seven minutes the cyanogen was entirely absorbed, the spectrum being now that of the trace of water vapor from which the zinc cyanide could not be freed. It is difficult to see why a gas which if decomposed by the discharge would remain as the chemically inert nitrogen, should disappear at such an extraordinary rate. To test the matter further another tube was made in such form that when the vacuum became higher than a certain value, a portion of the current was shunted through a platinum wire surrounded by zinc cyanide, and so the vacuum was automatically maintained nearly constant. This tube was worked for four hours, and the yield and absorption of the gas went on for the whole time at a nearly constant rate.

Tube containing lead ferrocyanide, yielding nitrogen when heated, also gave considerable water vapor. Sealed at a slightly lower vacuum than the first, yet the nitrogen all vanished in ten minutes, water alone remaining. As it was possible in these two cases that the gases had undergone reabsorption upon the cooling of the substances from which they had been expelled, a fresh portion of the gases was driven off and the tubes allowed to stand twenty-hours. No change could be observed in them.

Tube containing iodine.—The iodine was shut off from the main tube by a stopcock, fearing its vapor tension at ordinary temperatures would be too great to admit of obtaining a sufficiently high vacuum. The tube was exhausted, the stopcock opened for a moment to fill the tube with iodine vapor, and the exhaustion repeated. After sealing, the iodine disappeared under the action of the current in less than a minute. The tube was filled with iodine vapor again by opening the stopcock and warming the tube. Upon again starting the current the platinum mirror upon the glass at the cathode was seen to be attacked and converted into a dark bronze-colored substance and the iodine again disappeared.

Tube containing oxide of mercury, yielding oxygen when heated, but no water vapor. Tube pumped and heated very thoroughly, and when sealed showed the spectrum of oxygen and the red hydrogen line faintly. The vacuum rose slowly; after fifteen minutes the hydrogen line disappeared; at the end of an hour the vacuum had become quite high, the spark in parallel with the tube being two inches, but the current still passing easily. The spectrum of the tube then consisted of three lines of oxygen.

Experiments were also made with carbon dioxide and some other gases, the details of which need not be given here, inasmuch as it was found that oxygen was absorbed far more slowly than any other substance tried. Mercury oxide is also eminently adapted to maintaining a condition of constant vacuum. It yields oxygen only at a high temperature, and the flow of gas ceases immediately upon withdrawal of the source of heat.

To construct an X-ray tube in which the vacuum may be maintained at the most efficient point, it is only necessary to attach near the anode terminal a short tube having a sealed-in platinum wire packed around with oxide of mercury. A plug of asbestos may be used to hold the substance in place. When by use the vacuum becomes too high, a portion of the current is shunted from the cathode through the oxide of mercury for a brief time; a little gas is dislodged and the tube becomes as new. The shunt may be left permanently in place with a longer or shorter spark-gap at the mercury terminal. The action will then be automatic, and vacuum remain indefinitely at any desired point.

Searles Physical Laboratory,
Bowdoin College, November, 1898.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Extraction of Nickel by the Mond Process.*—A paper by **Roberts-Austen** has recently appeared giving an account of the application of the volatile nickel-carbonyl, discovered by Mond, to the extraction of nickel from its ores. Mond's discovery was that metallic nickel forms a volatile compound with carbon monoxide, which he called nickel-carbonyl, which boils at 150° and from which the nickel may again be regenerated by heating to 180°. Iron, while not as active, acts similarly. The suggestion was an obvious one, that by means of these volatile compounds, these metals might be separated from cobalt, copper and the others with which they are associated in their ores. An experimental plant was erected in 1892 near Birmingham. The material used was Bessemerized matte, which after roasting contained 35 per cent nickel, 42 per cent copper and about 2 per cent of iron. By treatment with sulphuric acid, about two-fifths of the copper was removed, the residue containing 51 per cent of nickel. The remaining copper was reduced to the metallic state by means of water gas at 300°. The ore was then treated in a volatilizing tower with carbon monoxide, the temperature being kept below 100°. The volatile nickel carbonyl passed to a decomposer—a horizontal retort heated to 180°—where the nickel was released in the metallic form and the carbon monoxide returned to the volatilizer to be again used. The unused metallic residue was returned to the roasting furnace. The nickel produced was 99·8 per cent pure. Up to the time Professor Roberts-Austen visited the plant, about 80 tons of nickel had been thus prepared, with quite satisfactory results.—*Nature*, lix, 63, November, 1898.

G. F. B.

2. *On Ætherion.**—A note on ætherion has been published by **Crookes**, giving some of his old researches made from 1873 to 1881, tending to show that the new gas may be nothing more than aqueous vapor. Early in his investigations he noticed that a little aqueous vapor thrown into the vacuum [of a radiometer], converted into attraction the repulsion due to radiation. In 1880, he observed that aqueous vapor was found to retard the force of repulsion to a great extent and carbonic acid acted in a similar way, though less in degree. "The presence of even a trace of aqueous vapor was found to have a strong action in diminishing the sensitiveness of the radiometer and other instruments," he says. As to the absorption of ætherion by glass and its evolution again on heating, the author gives an experiment made in 1879 showing that air-dry glass condenses on its surface a considerable quantity of water and carbonic acid which does not come off

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* This Journal, IV, vi, 431, November, 1898.

until heat is applied. As to its conductivity for heat, experiments are described which show that at high vacua water gas is a better conductor than either air or hydrogen at similar pressures. "It has been found," he says, "that as water gas is rarefied, its heat conductivity diminishes in a greater ratio than that of hydrogen." "At these high vacua water gas gains so rapidly on hydrogen that I am prepared to believe that at Mr. Brush's low pressure of 0·38 millionth, the ratio may even be as great as that he ascribes to etherion." "On the evidence at present available," he concludes, "I consider it more probable that ætherion is water vapor than that it is a new elementary gas."—*Chemical News*, lxxviii, 221, November, 1898. G. F. B.

3. *On the Preparation of Graphitic Acid.*—An easy method of preparing graphitic acid has been described by STAUDENMAIER. A mixture is first made of 100^{cc} of concentrated nitric acid (sp. gr. 1·4) and 300^{cc} of ordinary strong sulphuric acid. To this are added 50 grams of pulverized Ceylon graphite, and then 100 grams of potassium chlorate, in small portions at a time; the whole being frequently stirred. After the mixture has stood for several hours, it is poured into water, and the solid is washed, dried and ignited in a large dish of metal until it has intumesced. Then it is again stirred with water, and the portion that floats is collected for use in the subsequent operations. Of this prepared graphite, 25 grams are poured, with constant stirring, into a cold mixture of one liter of strong sulphuric acid and half a liter of strong nitric acid contained in a shallow dish, and then about 450 grams of potassium chlorate are added in successive portions. After the active evolution of gas diminishes, and a sample of the resulting green substance appears pure yellow on treating it with acid permanganate, the whole is poured into water, and the resulting solid is washed repeatedly by decantation. It is now placed in a dish and a solution is added to it consisting of seven grams of potassium permanganate dissolved in 120^{cc} of hot water; after cooling, a mixture of 15^{cc} of strong sulphuric acid with 75^{cc} of water is added, and the whole is heated on the water bath until the red color has disappeared. Hydrogen peroxide is added, the whole is allowed to stand at rest for some time with occasional stirring, and the graphitic acid is then washed first with dilute nitric acid and finally with alcohol and ether.—*Ber. Berl. Chem. Ges.*, xxxi, 1481-7, June, 1898. G. F. B.

4. *On Compounds of Lithium and Calcium with Ammonium.*—The fact has been observed by MOISSAN that when liquefied ammonia, contained in a tube cooled to —50°, is brought in contact with metallic calcium or lithium, solution takes place with the production of an intense blue liquid having a brown red reflection; this result being comparable to the similar phenomenon observed with potassium and sodium. These latter metallic ammoniums when thus produced, according to Joannis, have the formulas KNH_3 and $NaNH_3$, and they decompose at the ordinary temperature and pressure, evolving ammonia gas and regenerating

the alkali metal in brilliant crystals, as Seely long ago pointed out. As opinions differ as to whether these metallic ammoniums are molecular or atomic in constitution, the author has made experiments with potassium, sodium, lithium and calcium. Each metal was placed in a U-tube of glass, one leg of which was drawn out fine, while the other was recurved and connected with a source of ammonia gas, dried first over fused potassium hydrate and then over sodium. The four tubes were united successively so that the same current of ammonia gas traversed them all. By the use of a water bath, the temperature could be regulated, and the flow of gas increased or diminished by means of a tap. For low temperatures acetone was used in the bath, being cooled even as low as —75°, the solidifying point of ammonia, by adding to it fragments of solid carbon dioxide. The experiments were made under atmospheric pressure. It was found that lithium was attacked at +70° with liquefaction, calcium at +20° without liquefaction, potassium at —2° with liquefaction, and sodium at 20° with liquefaction. It is clear therefore that these four metals unite directly with ammonia gas, the temperatures obtained being the superior limits of the action and at the same time the decomposition-temperatures of the metallic ammoniums under the conditions. By preparing the metallic ammonium by the action of the liquefied gas, and then slowly raising the temperature, the inverse method was effected, the sodammonium dissociating at —20° and giving the metal and ammonia gas, and the potassammonium doing the same at —2°; while calcium-ammonium and lithium-ammonium were stable at the ordinary temperature and pressure. Moreover, ammonia gas solidified at —80°, does not attack either of the four metals, though action takes place as soon as liquefaction commences with evolution of heat. If the experiment is made slowly, the author states that amides of these metals are produced; while when it is rapid, the metallic ammonium may be readily produced at the ordinary pressure and the metal regenerated in crystals without the production of amides. Lithium placed in a U-tube at the temperature of the laboratory and subjected to a current of ammonia gas, takes a brownish-red tint and liquefies, producing a liquid of the same color. Heated rapidly to +70°, the excess of ammonia escapes, leaving a reddish-brown solid, which takes fire in contact with the air. If lithium be placed in liquefied ammonia, the tube being allowed to return slowly to the ordinary temperature, the dark blue liquid becomes thicker, reaching a sensibly constant composition after 24 hours. The composition then was found to be: NH_3 89·04, 87·00, 88·72, and 88·37 in four samples; the formula $(NH_3)_3Li$ requiring 87·93. The liquid may therefore be considered either as a saturated solution in ammonia gas or as a compound $NH_3Li.(NH_3)_2$. As to solid lithium-ammonium, its composition was determined (1) by weighing the ammonia fixed by the metal and (2) by preparing the compound and determining the ammonia in it. The lithium found in five experiments was 28·07, 28·40, 28·72 and 28·82 per cent.; the ammonia being 71·93, 71·60, 71·28 and 71·18. Theory requires for NH_3Li, 29·16 of lithium and 70·83 of ammonia. It is much less soluble in liquid ammonia than the sodium compound. The metal calcium exposed at 15° to a current of ammonia gas takes a yellowish-brown tint, becomes heated and increases in volume. At a temperature between 15° and 20° only a solid compound is formed, which takes fire in contact with the air and which fixes liquid ammonia and becomes pasty, being then soluble in the liquid. Like lithium, it gradually decomposes at the ordinary temperature, yielding transparent crystals of amide $(NH_2)_2Ca$ and evolving hydrogen. On analysis calcium-ammonium gives numbers agreeing with the formula $(NH_3)_4Ca$.—*C. R.*, cxxvii, 685–692, November, 1898. G. F. B.

5. *On the Spectra of Iodine.*—The results of a measurement of the lines in the emission and absorption spectra of iodine from wave-length 3030·5 to wave-length 6191, expressed in Ångström units, have been given by Konen. As is well known, either a line spectrum or a band spectrum can be obtained in a vacuum tube. The latter is composed of two different portions which may be designated as B_R and B_V; the former of these, B_R, is identical with the absorption band spectrum, while B_V is not. When the discharge is very intense, however, B_R disappears, while B_V increases in intensity; so that the author is inclined to the view that B_R is due to the ordinary iodine molecules, and B_V results from dissociation. In the line spectrum also, two series may be distinguished, but it is quite possible that in this case the second series may be produced by an impurity. Tables of the wave lengths are given in the paper.—*Ann. Phys. Chem.*, II, lxv, 257–286, 1898. G. F. B.

6. *A Manual of Chemical Analysis, Qualitative and Quantitative;* by G. S. Newth, Demonstrator in the Royal College of Science, London; 8vo, pp. xii, 462. New York, 1898 (Longmans, Green and Co.).—The author tells us in the preface to his book that he has "done his best to make it as little of a cram-book as possible, but has endeavored to teach *analytical chemistry* as well as analysis—that is, the theoretical as well as the practical side of the subject." Book I treats of Qualitative, Book II of Quantitative Analysis. The quantitative work is divided into gravimetric methods, including electrolysis, and volumetric methods, including gas analysis; special methods following these. The great convenience of having the leading facts well set forth in a work of moderate size, for the use of students taking short courses, is well exemplified in this manual. The portion on volumetric work seems especially good. G. F. B.

7. *Stratified Brush Discharges in Atmospheric Air.*—M. Toepler has described a species of stratification in brush discharges (Wied. Ann., lxiii, p. 109, 1897) and the present paper is a continuation of his studies in this direction. A sixty-plate Toepler-Holtz machine was employed, and it was found that the increase of potential-difference was closely proportional to the

increase of sparking distance; and that the potential difference at the electrode is nearly independent of the current strength if the discharge is of the nature of a brush. The G. Wiedemann-Hittorf law for Geissler tube discharges therefore holds also for brush discharges in free air.—*Wied. Ann.*, No. 12, 1898, 660–675.

The writer has substantiated the results of Toepler, as far as relates to the stratification, by the employment of an apparatus which can produce a difference of potential of three million volts. The stratification with this high voltage occurs in the neighborhood of the positive pole. J. T.

8. *The Spectrum of Lightning.*—Photographs of the light of a spark six feet in length, taken in the Jefferson Physical Laboratory, show atmospheric lines very strongly developed between E and H. No more lines were produced by a voltage of three million than can be brought out with a voltage of one hundred thousand. With the higher voltage, however, there is a complete absence of the metallic lines of the terminals. The photographs taken with the high voltage therefore must closely resemble the spectrum of lightning. J. T.

9. *Dispersion in the Electrical Spectrum.*—Observations on dielectric constants for periods between wave lengths 2^{cm} to 75^{cm} have hitherto been wanting. E. Marx has endeavored to supply this break in the subject and has applied to his results certain laws of dispersion. He speedily ascertained that in order to obtain very short electrical waves it is necessary to so interlock the primary and secondary circuits, or in other words the exciting and resonating circuits, in such a manner that only the fundamental vibrations of the primary circuit were in evidence. He employed Drude's method of measurement, which consists in nodes measureing the displacement of the electrical waves on wires, when a portion of these wires are surrounded by a dielectric. By means of an exciter of small dimensions he obtained electrical waves, 4^{cm}, 36^{cm}, and 58^{cm} in length. The positions of the nodes were ascertained by means of a Zehnder-Geissler tube. The index of refraction of electric waves, $3 \cdot 2^{cm}$ in length, for water was found to be

$$n^2 = 85 \cdot 0 \text{ (at } 17^\circ \text{ C.)}$$

For wave length 36^{cm}

$$n^2 = 82 \cdot 50 \text{ (at } 17^\circ \text{ C.)}$$

For wave length 53^{cm}

$$n^2 = 83 \cdot 73 \text{ (at } 17^\circ \text{ C.)}$$

The indices of refraction of ethyl-alcohol were similarly investigated. It was surmised that absorption bands of great extent in the ultra-red modify existing dispersion formulæ. A difference in concentration of the ethyl-alcohol solutions of 1 per cent can change the square of the electrical index of refraction 35 per cent. —*Wied. Ann.*, No. 11, 1898, pp. 411–434; ibid., No. 12, 1898, pp. 597–622. J. T.

10. *Traité Élémentaire de Méchanique Chimique fondée sur la Thermodynamique* par P. Duhem. Tome iii, Les Melanges

homogènes; les dissolutions, pp. 1–380. Paris, 1898 (Librairie Scientifique A. Hermann).—The third volume of the extensive work by M. Duhem, which was announced in volume iii, p. 419, of this Journal, has now been issued. It shows that the promises made at the outset are being thoroughly fulfilled, and that the work when completed will occupy a unique place in scientific literature.

The volume is divided into two parts; the first of these discusses homogeneous mixtures with respect to thermodynamic potential, osmotic pressure and the hypotheses of Van t'Hoff and d'Arrhenius; also chemical reactions in homogeneous systems. The second is devoted to solutions, discussing the solution of salts in general, the effect of vaporization of the solvent, with the formulas of Kirchhoff, the effect of freezing of the solvent, saline and gaseous hydrates, and double salts. This enumeration of the subjects of leading chapters will serve to show the scope of this part of M. Duhem's work, but only close study will make the reader familiar with the thoroughness of the discussion as a whole.

11. *Prismatic and Diffraction Spectra. Memoirs of Joseph von Fraunhofer.* Translated and edited by J. S. AMES.—The inauguration of the series of *Harper's Scientific Memoirs* was announced in the last number of this Journal (p. 504, Dec., 1898). The second volume has now been issued; it contains translations of Fraunhofer's classical papers (1817–1828). To these are added the note by Wollaston (1802) describing the method by which he obtained a pure solar spectrum and discovered the presence of fixed lines in it. This volume, like its predecessor, is edited by Prof. Ames.

II. GEOLOGY AND MINERALOGY.

1. *Maryland Geological Survey;* WILLIAM B. CLARK, State Geologist. Vol. i, pp. 1–539, plates i–xvii, 1897; Vol. ii, pp. 1–509, plates i–xlviii, figures 1–34, 1898.—Maryland was one of the first four states in the Union to institute an official geological survey, and, in the present series, is preparing the most elaborate and elegant geological reports that any state has so far produced. This second official survey of the state was organized by act of the General Assembly in March, 1896. The commission appointed Prof. Wm. B. Clark state geologist, and the two volumes are the work of the first and second years of the survey. The first volume, as the geologist says in the preface, "consists primarily of a summary of past and present knowledge concerning the physical features of Maryland, and embraces an account of the geology, physiography and natural resources of the state. The "Historical sketch," comprising Part ii, begins with the landing of Captain John Smith, in 1608, and narrates the work of the successive explorers and investigators who have developed the knowledge of the resources of the state. Part iv, on the Bibliography and Cartography, is compiled by Mr. E. B.

Matthews and includes a list of the works and maps published relating to the physiography, geology and mineral resources of the state, from 1526 to 1896, inclusive, and Part v is the first report by Mr. L. A. Baur on the magnetic work in Maryland, including the history and object of magnetic surveys in general.

Volume ii, in addition to the state geologist's administrative report on the operations of the survey during 1896, and during 1897, contains in Part ii an elaborate paper by Messrs. George P. Merrill and Edward B. Matthews, on the Building and Decorative Stones of Maryland, illustrated by beautiful colored pictures of some of the more important stones as polished, and micro-photographs of their structure. Part iii is an equally elaborate report on Cartography, to which Mr. Gannett, of the United States Geological Survey which is coöperating with the state survey, contributes a valuable paper on the aims and methods of cartography; and Mr. E. B. Matthews one on the maps and map-makers of Maryland.

The volumes are printed on excellent paper, and the illustrations are numerous and often of great beauty as works of art, and nothing seems to be spared to make the reports models of their kind.

H. S. W.

2. *The Lower Cretaceous Gryphæas of the Texas Region;* by R. T. HILL and T. W. VAUGHAN. Bull. No. 151, U. S. Geol. Survey; pp. 1–139, plates i–xxxv. Washington, D. C. 1898.—At last the *Gryphæa pitcheri* Morton, and the age of the Tucumcari beds, have been set at rest. Mr. R. T. Hill has succeeded not only in solving, but in clearly demonstrating his solution of the perplexing problems regarding the Lower Cretaceous beds of Texas and neighboring regions, in showing the true order of the beds and their faunas. In this work, one of the greatest difficulties has arisen from the great variability of the Gryphæas which have served as *leitfossilien*, and from the confusion arising from mis-naming, and careless (or worse) statements regarding their occurrence and distribution. Mr. Hill, with the assistance of Mr. Vaughan, has made an exhaustive study of the whole group of Gryphæas, and determined and illustrated with numerous figures the characters of the species, their developmental history and their stratigraphic range and geographical distribution. The names of the Gryphæas (to which the name *G. pitcheri* has been applied) which survive the searching investigation are *G. corrugata* Say, *G. navia* Hall, *G. mucronata* Gabb, *G. washitaensis* Hill and *G. Newberryi* Stanton. Two new species, *G. Wardi* and *G. Marcoui*, are described. Particular attention should be called to the ontogenic study of the several species according to the Hyatt school of paleontologists.

H. S. W.

3. *Bibliographic Index of North American Carboniferous Invertebrates;* by STUART WELLER. Bull. No. 153, U. S. Geol. Survey, pp. 1–653, 1898.—The indexing and classifying of the innumerable facts regarding fossil species is a necessary prep-

aration for the new paleontology, which deals with the history of organisms rather than their form and description alone. Mr. Weller has not only opened the way for his own investigation in this direction, but has rendered a great service to all advanced students who are engaged in paleontological investigation. The matter is well arranged and the necessary statistics are given with precision and will enable the student to turn at once to the original sources of information. H. S. W.

4. *Contributions to the Tertiary Fauna of Florida, etc.;* by WM. H. DALL. Vol. iii, Part iv.—I, Prionodesmacea: Nucula to Julia, II, Teleodesmacea: Teredo to Erville; (Trans. Wagner's Free Inst. of Sci. of Philadelphia), pp. 571–947, plates xxiii–xxxv, April, 1898.—This volume maintains the characteristics of its predecessors;—the beautiful, sharply-defined illustrations and the clear and exhaustive descriptive parts, which are carried out in many cases to a thorough revision of classification of the larger divisions and the distribution of the known species, leave little to be desired in the discussion of such a group of fossil mollusca.
H. S. W.

5. *Contributions to Canadian Paleontology;* by J. F. WHITEAVES; vol. i, part v, pp. 361–436, plates xlviii–l; Geol. Survey of Canada, No. 659, 1898.—This closing part of the first volume of contributions to Canadian Paleontology is chiefly concerned with the thorough revision of the nomenclature and faunas particularly noted in the previous portions of the volume, the first of which was issued in 1885.

In the first papers, the Hamilton fauna of Thedford, Widder and neighborhood in Ontario is thus revised; the additions are based upon new collections made by Mr. Schuchert, for the National Museum, in 1895 and Canadian collections examined by the author; and the revision of nomenclature is of particular importance as expressing the comparative study, of both Mr. Whiteaves and Mr. Schuchert, on large and widely distributed collections. The final list recognizes 226 species in the fauna. The second number of the part is an appendix on revision of nomenclature and statements in previous numbers of the volume. The volume being now complete, a special title page is issued with directions for binding the whole. H. S. W.

6. *Geological Survey of Canada*, G. M. DAWSON, Director, Ann. Rept. (new series), vol. ix, for 1896, pp. 816, five maps, twenty plates, Ottawa, 1898.—In addition to the summary report (614) of the operation of the survey for the current year 1896, the volume contains Tyrrell's report on the Doobaunt, Kazan and Ferguson rivers, etc. (part F), Bell's report on the French river sheet (I), Low's report on the northern part of Labrador peninsula (L), Bailey's report on S. W. Nova Scotia (M), Hoffmann's report on Chemistry and Mineralogy (S) and Ingall's report on Mineral Statistics. All of them except the Tyrrell report have been previously noted (see this Journal, iii, p. 421; iv, 78, 232, 434 and 510). H. S. W.

7. *Report on the Doobaunt, Kazan and Ferguson Rivers and the Northwest Coast of Hudson Bay, etc.;* by J. B. TYRRELL. Geol. Surv. of Canada, Ann. Rept. 1896, vol. iv, part F, pp. 1–218, plates i–xi and three maps, 1897.—This report gives account of explorations carried on during the years 1893 and 1894, in a region lying north of the 59th parallel of latitude and west of Hudson Bay, covering about 200,000 square miles. It contains much valuable geological information; a study of the movement of glaciers over the region; appendices on Chippewyan and inland Eskimos vocabularies; and a third one on plants collected by J. W. Tyrrell. H. S. W.

8. *Rivers of North America, a reading lesson for students of geography and geology;* by ISRAEL C. RUSSELL; pp. 1–327, figures 1–23, plates i–xvii. New York, 1898 (G. P. Putnam's Sons).—Prof. Russell's "Rivers of North America" is a fit companion for "Lakes of North America," "Glaciers of North America" and "Volcanoes of North America" by the same author. It is a delightful "reading lesson" for any one interested in geography or geology and will make brooks and rivers more attractive to the lover of nature. The characteristics of stream action are presented clearly in plain language without detailed discussion of laws or theories, and each point is illustrated from American rivers. The chapters on "Stream Development" and "The Life History of a River" trace the stream's history from youth to old age, tell of its birth, its efforts to adjust itself to its environment and the accidents which it may suffer. The river is made to appear as a thing of life. Students who have searched through manuals, geological reports and scattered essays for facts and laws of stream action will be thankful for the discussion of these subjects here given. H. E. G.

9. *Earth Sculpture or the origin of land forms;* by JAMES GEIKIE; pp. 1–397, pl. i–ii, figs. 1–89. New York, 1898 (G. P. Putnam's Sons).—This volume is the latest number of The Science Series published by the Putnams. The book treats first of the agents of denudation and the resulting land forms in regions of horizontal, inclined, folded and displaced strata. After this the modifying effects of igneous, glacial and æolian action on surface features are discussed. "Coast Lines" and "Classifications of Land Forms" are very useful chapters. The book is addressed to the average student who may desire some general knowledge of the development of land forms, and we know of no other English work which gives a general account of the whole subject. To American readers some of the terms and descriptions of foreign localities will seem unfamiliar and the glossary in the Appendix will be needed. This is particularly true of the divisions of the Geological Time Scale.

As an introductory treatise Prof. Geikie's book is very welcome and students of nature who have mastered this will read Sir A. Geikie's "Scenery and Geology of Scotland," Lubbock's "Scenery of Switzerland," Powell's "Canyons of the Colorado" and other physiographic classics with added interest. H. E. G.

10. *Elemente der Gesteinslehre*, von H. ROSENBUSCH. 8vo, pp. 546. Stuttgart, 1898.—This book is based, as the preface states, on the lectures of the author at Heidelberg. While it claims to be only an elementary treatise, it is much more than that, and will be read with interest by every petrologist as giving the latest views of its author and an excellent résumé of the present state of the science from a certain, rather subjective, standpoint.

After an introductory chapter on the general principles of petrography and the composition, structure and classification of rocks, the author describes not only the igneous rocks, to which his previous volumes have been devoted, but also the sedimentary rocks and crystalline schists.

In the portion devoted to the igneous rocks, the essexites, shonkinites and missourites have been raised to the rank of groups of the same order as the granites. The monzonites, for which Brögger has proposed a similar position, are left as a subdivision of the syenites, while among the effusive rocks a group of trachydolerites has been formed. These, according to Rosenbusch, are homologous with the essexites, but, though they resemble these in being intermediate, the examples and analyses which are given resemble more closely Brögger's monzonites. The necessity for the recognition of such groups of intermediate rocks is urgent, but this group, as here given, is the least satisfactory of all, embracing as it does many types which differ much among themselves, and it seems probable that it will undergo many changes and subdivisions in the future. It may be suggested that the name *latite* previously proposed by Ransome seems preferable to the coextensive term of trachydolerite used by Rosenbusch.

The sedimentaries are very fully and satisfactorily treated and the same is true of the metamorphic schists. For schists derived from igneous rocks the author proposes the use of the prefix *ortho*, and for those derived from sedimentaries the prefix *para*, so that we would have orthogneiss, paragneiss, etc.

In general the views held by the author are the same as those expressed in his previous works. The age distinction is practically banished, but traces of it still survive among the effusives.

The chemical characters of the various rocks are discussed in considerable detail, and a valuable feature is the insertion of tables of typical analyses, not only of the rocks themselves but of their component minerals, many of which are published here for the first time. They are in general well selected, but the almost total lack of references throughout the book, especially for the analyses, is to be deplored, even though such omissions are due to the elementary character of the work.

But such criticisms are chiefly matters of personal opinion, and the name of the author is sufficient guarantee for the high character of the volume. It should prove a valuable text-book for the German-reading student, and will be a much used addition to the library of every petrologist. H. S. W.

11. *The Educational Series of Rock Specimens collected and distributed by the U. S. Geological Survey;* by J. S. DILLER. Bulletin No. 150, U. S. Geol. Surv., Washington, 1898, pp. 400, 47 pl.; price 25 cts.—A number of years ago the United States Geological Survey undertook the praiseworthy task of collecting and distributing to our leading educational institutions, as an aid in geological teaching, a series of rock collections illustrating the petrology of the United States. Under the able management of Mr. J. S. Diller, aided by many geologists both of the Survey staff and from other portions of the country, this task was sucessfully completed, and about 250 sets, comprising over 150 specimens in each, were distributed. In addition, to supplement the value of these collections, the Survey has now issued the volume above mentioned, in which the rocks are described from the standpoint of modern petrography. Under the editorship of Mr. Diller, who also contributes largely to the descriptive matter, the rocks have been described by a number of specialists, in great part those by whom they were collected, and to whom is due our knowledge of the geology of the regions in which they occur.

The method of classification is simple and rational, and the volume constitutes in fact an excellent practical text-book of petrology for Americans, and as such will be found of very great service to teachers of geology, as well as to those engaged in the more specialized petrographical branches. Its appearance in connection with the use of the collections cannot fail to give an impulse to the study of petrography, and the Survey staff in general, and Mr. Diller in particular, deserve great credit for the completion of this useful and public-spirited work. L. V. P.

12. *The Mechanical Composition of Wind Deposits;* by JOHAN AUGUST UDDEN, pp. 1–69. Augustana Library Publications, No. 1. Rock Island, Ill., 1898.—The author has carried on a long series of observations in order to show the part played by the air in motion in transporting sand deposits to different distances as determined by their size. Four classes are especially recognized: (1) lag gravels or coarse residue deposits in the rear of sand dunes; (2) drifting sand, constituting the sand dunes of dry and sandy regions; (3) fine sand, soon dropped by the wind in the lee of drifting dunes; (4) atmospheric dust, which only slowly settles out of the air far away from the place where it was raised.

Many observations in regard to each of these have been made at different points, chiefly in Illinois, Indiana, Nebraska, Kansas and the Dakotas. The results, given in the form of numerous tables, show the percentage of particles of characteristic size present under the given conditions. For example, lag gravels, though varying widely in different localities, include chiefly particles from 4^{mm} to $\frac{1}{4}^{\mathrm{mm}}$ in diameter; drift sands those from 1^{mm} to $\frac{1}{8}^{\mathrm{mm}}$; dune sand is more uniform, from 60 to 70 or 80 per cent of the particles ranging between $\frac{1}{4}$ and $\frac{1}{8}^{\mathrm{mm}}$; lee sand runs down to $\frac{1}{16}^{\mathrm{mm}}$ or smaller, and atmospheric dust varies from $\frac{1}{8}$ to $\frac{1}{128}^{\mathrm{mm}}$ and smaller. The approximate maximum distances over which quartz fragments may be lifted by moderately strong winds in single leaps are estimated as follows:

Gravel (8–1^{mm} diam.)	A few feet.
Coarse and medium sand (1–$\frac{1}{4}^{mm}$)	Several rods.
Fine sand ($\frac{1}{4}$–$\frac{1}{8}^{mm}$)	Less than a mile.
Very fine sand ($\frac{1}{8}$–$\frac{1}{16}^{mm}$)	A few miles.
Coarse dust ($\frac{1}{16}$–$\frac{1}{32}^{mm}$)	200 miles.
Medium dust ($\frac{1}{32}$–$\frac{1}{64}^{mm}$)	1000 miles.
Fine dust ($\frac{1}{64}^{mm}$ and less)	Around the globe.

A striking result brought out is the comparative definiteness with which the different grades are separated from each other by the sorting action of the wind. In closing, the author discusses briefly the relation of the facts brought out by his investigations to the origin of the loess deposits, which in their mechanical composition certainly resemble atmospheric sediments. He does not regard it possible, however, to reach a final conclusion from the data at hand.

13. *Brief notices of some recently described Minerals.*—SENAITE is a new mineral, related to ilmenite, described by Hussak and Prior. It is found in rounded fragments and rough crystals in the diamond-bearing sands of Diamantina, Minas Geraes, Brazil. Crystallization like ilmenite, rhombohedral-tetartohedral (trirhombohedral). Hardness about 6, specific gravity of crystals, 5·30, massive 4·78 to 4·22; luster sub-metallic and color black, in thin splinters, greenish. Analysis gave:

	TiO_2	PbO	FeO	Fe_2O_3	MnO	MgO	SnO_2
G...4·78	57·21	10·51	4·14	20·22	7·00	0·49	0·11=99·68

The formula (Fe, Pb) O.2(Ti Mn) O_2 is suggested, but doubtful.—*Min. Mag.*, xii, 30, 1898.

MOSSITE is a name given by Brögger to a nisbo-tantalate of iron occurring with yttro tantalite at Moss, Norway. It is found in black tetragonal crystals with $\dot{c} = 0·644$. The crystals are mostly twins with (101) as twinning plane; they are often distorted by elongation parallel to (111) as is sometimes observed with rutile. An analysis gave $(N6,Ta)_2O_5$ 82·92, FeO 16·62, SnO_2 0·18 = 99·72, which corresponds to the formula Fe $(N6, Ta)_2O_6$; further it was found that N6 : Ta = 1 : 1. The author shows that mossite is near tapiolite, which, however, is richer in Ta_2O_5 and has $\dot{c} = 0·652$. He has also made the interesting observation that the crystals of "tantalite" which have long been figured in the text-books, are in fact identical with tapiolite, being twin crystals similar to those mentioned above.— *Vid. Skrift. Math.-nat. Klasse*, 1887.

VALLÉITE is a mineral closely related to anthophyllite occurring with the violet tremolite of Edwards, N. Y.; it is described by G. Cesàro. Crystallization orthorhombic; occurs in colorless prismatic crystals with the usual amphibole angles of 125° 30′ and 54° 30′. The cleavage is prismatic and pinacoidal. The hardness is 4·5, specific gravity 2·88. Analysis gave:

SiO_2	MgO	CaO	Fe_2O_3	MnO	K_2O	H_2O
58·02	27·99	5·04	1·28	2·88	0 89	3·13 = 99·23

The formula is $RSiO_3$, or that of anthophyllite, from which it is stated to differ somewhat in optical characters ($\gamma - \alpha = 0·0036$).—*Zeitschr. Kryst.*, xxx, 84.

Cedarite is a fossil resin, resembling amber, from the alluvium of the Saskatchewan river, Canada. Analysis gave: C 78·15, H 9·89, S 0·31, O 11·20, ash 0·45 = 100. Described by R. Klebs, *Jahrb. Min.*, ii, 212 ref., 1898.

Batavite, described by Weinschenk, is a decomposition product occurring with the graphite deposits near Passau, Bavaria. It occurs in white pearly scales with a specific gravity of 2·183. Analysis gave: SiO_2 42·33, Al_2O_3 16·35, MgO 28·17, H_2O 13·19 = 100 04. For this the composition suggested is $H_8Mg_4Al_2Si_4O_{19}$.—*Zeitschr. Kryst.*, xxviii, 160.

Grünlingite, described by Muthmann and Schröder, is a sulpho-telluride of bismuth, related to tetradymite, from Cumberland, England. It was earlier investigated by Rammelsberg, but the authors have obtained on analysis a composition agreeing with the formula Bi_4S_3Te or Bi(S, Te). It appears in cleavable masses with metallic luster and gray color; the specific gravity is 7·321. Named after Dr. F. Grünling of Munich.—*Ibid.*, xxix, 144.

Planoferrite, described by L. Darapsky, is a hydrated ferric sulphate from the Lautaro copper mine in Atacama. It occurs in tabular crystals which are colorless or lemon-yellow. An analysis gave: SO_3 15·57, Fe_2O_3 31·20, H_2O 51·82, insol. 1·41 = 100. This corresponds to $Fe_2O_3 . SO_3 . 15 H_2O$.—*Ibid.*, xxix, 213.

III. BOTANY AND ZOOLOGY.

1. *The Poisonous effect exerted on living plants by Phenols.* (Botan. Centralblatt, Nov. 15, 1898.)—Professor R. H. **True** has extended his fruitful investigations respecting the action of toxic substances far beyond the boundaries which he originally marked out. With efficient collaborators, he studied two years ago the effects of salts, acids, and bases, on one of the Leguminosæ, and had the satisfaction of having the results substantially confirmed by other experimenters, and the suggestions carried into a wider field. With Mr. Hunkel, he returns to the task, and obtains results which appear to confirm the belief that the whole subject of Toxicology is to receive abundant light from the study of plants. It is well known that the meagre information regarding the action of active remedial agents on plants, embodied in the Dispensatories, is unsatisfactory, but it certainly indicates a desire on the part of the commentators to get what little light glimmers through the obscure experimentation. Now, of late years, the whole subject has been placed on a different basis, and the work done upon this basis is creditable alike in its suggestion and its execution. It is not yet time to summarize the details or

attempt their complete co-ordination, but it is not too soon to predict that materials will before long be sufficient for a rational discussion of many obscure points in Toxicology and, we dare to hope, in Therapeutics. To the energy and carefulness with which Dr. True has prosecuted his work thus far, we owe most important contributions, and we trust he will be encouraged to carry his researches still further afield. The new paths which he has been instrumental in opening up are likely to attract many explorers. It is to be sincerely wished that all who enter the new field will bring to the work the same acuteness, patience, and thoroughness which seem to characterize the work thus far. To those of our readers who may like to know the thought which inspires the work, we may use words of Dr. True, which are abundantly justified. "The application of the theory of dissociation of electrolytes to explain the toxic action of acids, bases, and salts, on living organisms has yielded results of greatest import to both chemistry and biology." Now beyond these substances others are to be investigated by the same methods': let us hope with equally satisfactory results. G. L. G.

2. *On the peculiar mode of formation of pollen-grains in Magnolias.*—In the number of Comptes Rendus for Oct. 24, 1898, GUIGNARD gives an extremely interesting account of one of the puzzling exceptions to general rules, which are full of suggestions as to classification of organisms.

The author calls attention to the general characters of pollen formation which serve to separate more or less completely monocotyledons from dicotyledons. In the former, the first division of the nucleus of the mother-cell is followed by partition of the latter, and then the two daughter-cells divide in their turn, in the same way. In dicotyledons, on the other hand, the first nuclear division is not followed by partition of the mother-cell; that does not take place until after the second nuclear division, between the four nuclei which it has furnished.

Now to this general rule, Guignard had already pointed out a remarkable exception, namely, that among the monocotyledons are to be found plants which behave in this respect just as do the dicotyledons. These exceptions are the *Orchidaceæ*. They nearly all undergo simultaneous quadripartition of the pollinic mother cell. The author now announces that in the *Magnolias* is to be seen a type of division unlike either the first or the second. The type is almost intermediate between the two hitherto recognized, but by the formation of an incomplete partition (possibly sometimes complete) immediately after the first nuclear bipartition, is more like that of the monocotyledons than of the dicotyledons. G. L. G.

3. *Elements de Botanique.* P. VAN TIEGHEM. 2 volumes, 16mo. Paris, 1898.—In this revised edition of a helpful work, Professor Van Tieghem gives his own views regarding certain disputed points relative to structure, and states his reasons for suggesting a new classification of the higher plants. The princi-

pal features of this new system have already been presented in this Journal, and therefore need not be again spoken of in detail. But it seems proper to mention the fact that Professor Van Tieghem's system, although distinctly revolutionary, appears to offer advantages in practical ways, especially in bringing out clearly the disguised resemblances. The author has done good service in emphasizing a good many things which have been more or less overlooked in previous systems. It is not improbable that some of these things have been insisted on rather too strongly, and in this way, may throw the system somewhat out of proportion, but thus far, this does not seem to be the case. At any rate, the sense of general proportion is good, and, as a natural result, the perspective is not misleading. Teachers will find a good many fruitful suggestions in every part of the two volumes, but most of all in the portion devoted to classification. G. L. G.

4. *Sketch of the Evolution of our Native Fruits;* by L. H. BAILEY; pp. xiii + 472, 125 figures in text. New York, 1898 (The Macmillan Co.).—During the past ten years Professor Bailey has made a study of our indigenous fruits and of the cultivated varieties to which they have given rise. Some of the results of his investigations have already appeared in periodicals, and the present volume brings these scattered observations together and presents the whole subject in a more complete and connected form. The greater part of the book deals with the more important of our fruits, those which are most widely cultivated and which are consequently represented by the greatest number of cultivated varieties. These include the grape, the mulberry, our native plums, cherries and apples, the raspberry, the blackberry and the dewberry. The chapter on the grape, though particularly exhaustive, may indicate the scope of the work: in addition to a history and description of our various native grapes and of their cultivated varieties, it gives an account of the early attempts and failures to introduce the European grape into eastern America and concludes with a full bibliography of American grape literature. At the close of the book some attention is paid to our less important fruits, the gooseberries, currants, etc., which, although less widely cultivated, offer considerable promise to the cultivator.

A. W. E.

5. *Bush-Fruits: a Horticultural Monograph of Raspberries, Blackberries, Dewberries, Currants, Gooseberries, and other Shrub-like Fruits;* by FRED. W. CARD; pp. xii + 337, 113 figures. New York, 1898 (The Macmillan Co.).—The present book is the first of a proposed series of monographs dealing with the various types of American fruits. As its title indicates, it is distinctly horticultural and devotes its chief attention to a description of the varieties of the "bush-fruits" enumerated and of the methods employed in their cultivation. A. W. E.

6. *The Metamorphosis of Asterias pallida [A. vulgaris] with special reference to the fate of the Body Cavities;* by S. GOTO. Jour. College Science Imp. Univ. Tokyo, Japan, vol. x, pt. iii,

pp. 239–278, pl. xix–xxiv, 1898.—This important paper relates to the common northern starfish of New England. It is the result of work done at the Newport laboratory of Mr. A. Agassiz and at the Museum of Comp. Zoology of Harvard University. v.

7. *Zoological Results based on material from New Britain, New Guinea, Loyalty Islands, and elsewhere, collected during* 1895–1897; by ARTHUR WILLEY. Part I. Cambridge, Eng., Univ. Press.—The first article consists of a very detailed account of the development and anatomy of *Peripatus Novæ-Britanniæ*, sp. nov., illustrated by four plates. The second is devoted to a new species of Caprellidæ (*Metaprotella Sandalensis*). The third is on a sea-snake from the South Pacific, *Aipysurus annulatus* (Krafft), with figure. The fourth is a Report on the Centipedes and Millipedes, pl. vi. The fifth is on the Phasmidæ with notes on the eggs, pl. vii–ix. The sixth paper relates to the Pedapalp and Scorpions, pl. x, xi. v.

8. *An Account of the Crustacea of Norway, with figures of all the species;* by G. O. SARS. Vol. II, parts xi, xii. Oniscidæ, Bopyridæ, Dajidæ; 4to. Bergen. Published by the Bergen Museum, 1898.—This is a continuation of the admirable work of Professor Sars on the Norwegian Crustacea. This part contains eight autographic plates drawn by Dr. Sars himself, with his customary care and accuracy. This work is of special interest to American naturalists, because a considerable percentage of the species will be found also on our coast. v.

9. *The Mollusca of the Chicago Area: The Pelecypoda;* by FRANK COLLINS BAKER, pp. 1–130, with 27 plates. The Chicago Academy of Sciences, Bulletin No. iii, Part i of the Natural History Survey, Sept. 1, 1898.—This exhaustive and liberally illustrated memoir by Mr. Baker has recently appeared. A second part, devoted to the Gastropoda, is promised.

10. *Catalogus Mammalium tam viventium quam fossilium a* Doctore E.-L. TROUESSART, Parisiis. Nova Editio (Prima completa). Fasciculus IV, pp. 665–998; V, pp. 999–1264. Berlin, 1898 (R. Friedländer & Son).—Parts i–iii of the exhaustive Bibliography of papers relating to living and fossil mammals, by Dr. Trouessart, have already been announced in our pages. Parts iv and v have now appeared, embracing some six hundred pages and bringing this important work to a close. Part iv includes the Tillodontia and Ungulata: Part v the Sirenia, Cetacea, Edentata, Marsupialia, Allotheria, and Monotremata. The genera included in these two parts extend from Nos. 761 to 1588, and the species from Nos. 4086 to 7224; and besides there are many varieties not separately numbered. The whole bibliography is printed with admirable clearness.

11. *The Fishes of North and Middle America;* by DAVID STARR JORDAN and BARTON WARREN EVERMANN; pp. i–xxx, 1241–2183. Washington, 1898 (Bulletin 47 of the U. S. National Museum, Smithsonian Institution).—Part II of the complete descriptive catalogue of the fishes found in the waters of North

America north of the Isthmus of Panama, by Jordan and Evermann, has recently been issued. Part I was published in October, 1896. The third and final part with index, glossary, etc., is promised soon; it will be followed by a fourth volume which will be an atlas of plates.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Institute of France.*—At the session of the *Académie des Sciences* held at Paris, December 5, 1898, Professor O. C. Marsh of Yale University, to whom the Cuvier prize was awarded a year since, was elected Correspondent of the Academy.

2. *Annual Report of the Board of Regents of the Smithsonian Institution* showing the operations, expenditures and condition of the Institution to July, 1896; pp. i–li, 1–727; plates i to lxi.—This valuable report submitted to Congress by the Secretary, S. P. Langley, has recently appeared. The opening portion (pp. 1–77) are given to matters of administrative detail in regard to the work of the Institution in its different departments. The General Appendix (pp. 89–727) contains as usual a series of scientific papers on a wide range of topics, the republication of which in this place is a boon to many interested in science.

3. *Der Ursprung der Afrikanischen Kultur* von L. FROBENIUS, pp. i–xxxi, 1–368, with 5 folded charts, 9 plates and 225 illustrations in the text. Berlin, 1898 (Gebrüder Borntraeger).—This is the opening volume of what promises to be an extensive and important work, devoted to the origin of culture in general. The subject of the volume is the origin of culture in Africa, and this is treated with much fullness and abundance of illustration. Some of the topics discussed in detail are the weapons, shields, knives, etc.; also the various kinds of musical instruments, the different forms of huts and household utensils. The latter portion of the work deals with the physiological side of the subject in its varied aspects.

4. *Organic Evolution Considered;* by ALFRED FAIRHURST, pp. 1–386. Christian Publishing Co., St. Louis, 1897.—In regard to his work the author states: "I look upon the theory of evolution as being of no importance except as it involves the well-being of man. . . My object in what I have written is to promote the belief in theism and in the existence of a spiritual nature in man which theism alone can explain."

Catalogues recently issued.

Catalogue of Books and Papers on Chemistry and Physics, No. iv. Dulau and Co., 37 Soho Square, London, W., 1898.

Dr. F. Krantz, Rheinisches Mineralien-Contor in Bonn.—Katalog Nr. 1a (Siebente Auflage), Mineralien and Mineralpräparate, Mineralogische Apparate und Utensilien, pp. i–xii, 1–113, 1898.

Catalogue and Price List of Minerals for Scientific and Educational Purposes. Loose crystals a specialty. Roy Hopping, 5 and 7 Dey Street, New York City. 1899.

THE

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[FOURTH SERIES.]

ART. X.—*A Contribution to the Study of Contact Metamorphism;* by J. MORGAN CLEMENTS.

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THE various Huronian sediments which form a great portion of the iron-bearing districts of the Upper Peninsula of Michigan have in all of these districts been found to be penetrated by dikes of igneous rocks, which are predominately basic in character. The influence which these dikes exert in the formation of ore bodies where they cut the iron-bearing formations has been carefully worked out and described by Van Hise in numerous papers. The effects of contact metamorphism produced by the dikes upon the intruded sediments are of much less economic importance, and, to a very considerable extent, have been overlooked. In this paper I shall describe the products which have resulted from the intrusion of basic dikes in the Mansfield slate formation, a Lower Huronian iron-bearing formation of the Crystal Falls district of the Upper Peninsula of Michigan.*

The Mansfield formation, in its typical development, occupies a narrow valley, about three miles in length, through which flows the Michigamme River. In this valley there is situated the village of Mansfield and the mine of the same name. The formation consists of graywackes, slates (these predominate, hence the name), and phyllites, of demonstrably sedimentary origin. Associated with these, either as beds or as lenses agreeing in strike with the sedimentaries, we find slaty siderite, ferruginous chert and iron ore. The origin of the siderite and chert cannot be stated with certainty. The ore was derived from them by processes of metasomatism and concentration. All of these rocks, wherever exposed, are found to strike north and south, with at times slight variations from this direction, probably due to minor crumpling of the formation. The dip is high to the west at about 80°.

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* For details concerning the position which the Mansfield formation holds with reference to the other Huronian rocks, the reader is referred to an article entitled The Crystal Falls Iron-bearing District of Michigan, soon to be published in the 19th Ann. Rept. U. S. Geol. Survey, and in a Monograph of the Survey.

Overlying the Mansfield slates is the volcanic Hemlock formation.

Immediately east of the slates, that is, stratigraphically under them, there occur continuous masses of coarse dolerite (diabase), which cut off the slates in their strike, both to the north and to the south. No well-characterized dikes of dolerite cutting the Mansfield formation have thus far been found, either by surface studies or by underground exploration. In no instance, moreover, has a direct contact between the dolerites and the slate formation been observed, owing to the contacts being covered by disintegration products, although in many instances these rocks are separated from each other by spaces only a few feet in width. That the relations between the two, however, are those of igneous intrusion, is shown by the fact that the dolerites cut across the strike of the slates. Furthermore, if we make a traverse from the dolerites westward into the slates we notice the following. On the westward flank of the dolerite ridge we find associated with the dolerites masses of hard, peculiar, hornstone-like rocks, which have a well-banded character and in places are of large size and very numerous. Leaving this zone we reach the valley proper, in which lie the normal sedimentaries of the Mansfield formation. It thus appears that we have an intermediate zone between the dolerites and the slates. The banded rocks forming, with the associated dolerites, this intermediate zone, are believed to be sedimentary rocks which have been metamorphosed by the dolerites.

The exact original characters of these sedimentary rocks cannot be stated with positiveness. They are believed to have been slates having essentially the same general physical characters and mineral and chemical composition as the slates which now lie next to the contact zone and extend away from it for several hundred feet across the strike, without showing any noticeable changes in character. Although original chemical variations exist in these slates, as is shown by the banding, and did exist in the slates from which the metamorphosed products to be described were derived, as is shown by the banding in them,—nevertheless, such initial variations in these rocks is of a quantitative rather than qualitative character, and it is not believed that they can vitiate the conclusion concerning the effect of the metamorphic action upon the slates.

In the further discussion, therefore, it is assumed that the noteworthy differences between the rocks to be described are due to metamorphic action, and are not due to the original chemical differences. This assumption seems to be warranted by the fact that the changes are in perfect accord with those described from similar dolerite-slate contact zones in other areas.

The products of the contact metamorphism are those banded and spotted rocks which have been called spilosites, desmosites, and adinoles, and they will be the special subject of this article.

The dolerites (diabases) are coarse-grained, and do not exhibit anything of especial interest, consequently no description will be given of them. No evidence of any endomorphic action whatever has been observed in them.

In a study of contact action it is, of course, of the greatest importance to be able to determine accurately the order of succession from the unmetamorphosed to the most metamorphosed forms of the rocks. In the present case it is impossible to compare sections from, or analyses of, any given stratum of the rock at successive stages of approach to the line of contact, for the reason that, where the exposures were found, the dolerite had been intruded parallel to the strike of the slates. Moreover, the exposures are very poor, indeed. This order of succession has, however, been made out so satisfactorily for other localities by Lossen and others, and the characters of each rock in the succession have been so well described, that I have no hesitation, after microscopical study of thin sections of the specimens, in presenting the series in the following order. Beginning with the clay-slate, the least metamorphosed rock in the district, and the ones farthest removed from the intrusives, we pass to the phyllites, then to the spilosites and desmosites, and finally to those which are known as adinoles, the latter being those which occur next to the intrusive.

The Clay-slates.

These are dull and lusterless banded rocks, ranging in color from black to olive-green and red. They are usually impregnated with more or less iron pyrites in large macroscopical crystals. By high power, one can very readily distinguish in the slates round or oval areas of limpid quartz, surrounded by a dark grayish mass, which consists of minute flakes of white mica, crystals of rutile, and some of hematite, here and there a long, transversely-fractured, greenish needle, taken for actinolite, and, lastly, a dark grayish to black granular aggregate, which is the chief coloring matter of the slate, and which makes up a very considerable part of the rock. This aggregate is presumed to be of clastic origin, and to be chiefly feldspathic dust, darkened by carbonaceous and ferruginous specks. Careful search was made for flakes of chlorite and biotite, but no traces of either mineral could be found. Likewise, feldspar is absent in grains or crystals of a size which could be recognized. The banding of the slates is occasioned by the varying quantities of these minerals, although each band contains some individuals of all the kinds enumerated. All the crystals lie with their long axes parallel, causing the cleavage of the slate. It is clear that the slate is already in what we may perhaps call a semicrystalline state, the crystals of white mica, actinolite and rutile evidently being new developments in the sediments.

Origin and composition of the clay-slates.—The origin of the clay-slates of the Mansfield formation is probably to be looked for in the disintegration and decay of the Archæan granite and the subsequent compression of the resulting clay; for between the Archæan granites and the Mansfield slates no other rock masses are known to have existed in this region from which the clay could have been derived.

An examination of series of analyses of granites shows that while the relative percentages of soda and potash vary considerably, on the whole the potash is the higher of the two.

As a consequence of the easier solubility of the soda, this relation between the alkalies, soda and potash, is maintained, and is often very striking in clay-slates. An average of thirty-one analyses of clay-slates taken from various sources shows two and one-half times as much potash as soda. In the case of the Mansfield slate, it will be seen that the difference is much greater, there being present ten times as much potash as soda.

ANALYSIS OF MANSFIELD SLATE.

(By Mr. Geo. Steiger, U. S. G. S.)

SiO_2	60·28
TiO_2	·69
Al_2O_3	22·61
Fe_2O_3	2·53
FeO	·45
MnO	trace
CaO	·13
BaO	·04
MgO	1·35
K_2O	5·73
Na_2O	·54
H_2O at 100−	·60
H_2O at 100+	3·62
P_2O_5	·03
CO_2	none
C	·97
Total	99·57

The relative proportion of the alkaline earths, lime and magnesia, is also striking, the latter being present in the greater quantity. As a general rule, in igneous rocks (and to igneous rocks all clay-slates owe their ultimate origin) the reverse condition exists, i. e., the magnesia is subordinate in quantity to the lime, except in the ultra basic non-feldspathic kinds. The carbon present in this slate is considered as offering trustworthy evidence of the presence of organic life at the time of the deposit of the slates, though no more satisfactory evidence of the existence of life thus early has ever been found. It will be noticed finally that considerable water is present, but in consideration of the character of the rock this is to be expected, and if anything the value is low. These clay-slates are the rocks which are nearest the original sediments.

Phyllites.

The phyllites have a silky luster and bluish black color. They are composed essentially of white mica, which occurs in large quantity surrounding grains of quartz and feldspar (?). Rutile occurs in single crystals and in clumps of small crystals scattered through the mica. Associated with it, there occur here and there flakes of hematite, and small aggregates of black, undeterminable specks. Apparently, no interstitial material, such as occurs in the clay slates, is here present.

These rocks seem to differ from the clay slates only in that they are more completely crystalline, the interstitial material of the slates having disappeared. Owing to the apparently unimportant differences which exist between the clay-slates and the phyllites, no analyses have been obtained of the latter.

Spilosites, Desmosites, and Adinoles.

With these rocks we begin the consideration of the true contact products of the dolerite. These contact rocks possess certain characters in common. They are dense, flinty, "hornstone-like" rocks, which in some cases still show the fine banding of the original slates. Others are very characteristically spotted. They have a splintery, and at times almost conchoidal fracture, and vary in color on fresh fracture from light to very dark gray and greenish. The weathered surface, in almost all cases, is covered by a thin, white to light yellowish crust. The mineralogical components are quartz, feldspar (albite), biotite, chlorite, white mica, actinolite, rutile, epidote, and iron oxide. Various combinations of these minerals occur, and likewise the textures vary. As a result of these variations there are produced the different kinds of contact products known as spilosites, desmosites, and adinoles. The characters of the minerals showing nothing unusual, I shall briefly describe the textures and mineral combinations which characterize these various rocks.

Spilosites—The ordinary spilosites are distinctly mottled in the hand specimen, and show clearly to the naked eye in thin section the oval spots which characterize them. These oval areas are very commonly four millimeters long, and in rare cases even longer. They are frequently connected, forming chains. The spots are very appreciably darker than the mass in which they lie, and are composed of aggregates of chlorite, quartz, feldspar, and rutile, with a small amount of white mica. The chlorite is the chief constituent of the spots and gives them their dark color. The surrounding mass consists essentially of white mica, quartz and feldspar, small epidote and rutile crystals, flakes of hematite, and with a very slight amount of chlorite. The different proportions of chlorite and muscovite cause the difference between the spots and the groundmass. In some of the spilosites we find a few flakes of biotite and needles of actinolite. However, these are always very subordinate in quantity to the chlorite.

Other spilosites have been noted in this area in which the spots are white and lie in a fine-grained dark mass composing the greater part of the slides. So far as I can learn, only one similar instance of the occurrence of such a variety of spilosite has been described. This is by Van Werveke, to whose description reference is made by Zirkel* and Rosenbusch.†

The white spots are composed essentially of feldspar, with only a minor amount of chlorite and epidote. The feldspar grains are much larger than those which take part in the constitution of the mass surrounding the spots. This surrounding mass is made up of quartz, feldspar, chlorite, epidote, some sphene, with sheaves of actinolite scattered through it. In one section flakes of biotite were observed mixed with the chlorite, though in very subordinate quantity.

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* Zirkel. Lehrbuch der Petrographie, 2d edition, vol. ii, 1894, p. 719.

† Rosenbusch, Mikroskopische Physiographie, 3d edition, vol. ii, 1896, p. 1127.

ANALYSIS OF SPILOSITES.

	1.	2.
SiO_2	52·51	57·77
TiO_2	1·70	·92
Al_2O_3	19·00	19·35
Cr_2O_3	none	none
Fe_2O_3	3·31	1·29
FeO	7·19	3·37
MnO	trace	trace
CaO	1·55	1·71
BaO	trace	none
SrO	trace	trace
MgO	3·29	4·35
K_2O	·70	·22
Na_2O	6·72	8·22
Li_2O	trace	none
H_2O at 110°	·34	·18
H_2O above 110°	3·26	2·34
P_2O_5	·15	·04
CO_2	none	none
S and SO_3	none	none
C*		
Cl	none	none
F	trace	none
Total	99·72	99·76

No. 1, Spilosite, Spec. 32861 Lake Superior Division U. S. Geol. Survey, from Mansfield, Michigan, Dr. H. N. Stokes, analyst.

No. 2, Spilosite, Spec. 32827 Lake Superior Division U. S. Geol Survey, from Mansfield, Michigan, Dr. H. N. Stokes, analyst.

Desmosites.—Under the desmosites are included contact products composed of the same mineral constituents as the spilosites, but which instead of being spotted show a distinctly banded structure. That these are very closely related to the spilosites, and that in fact they grade into each other is shown by the study of one rock. A section from this, examined under the microscope, shows irregularly rounded areas which consist of ragged bunches of chlorite and aggregates of rutile and epidote, with some flakes of biotite lying in a quartz-feldspar mass. As these spots increase in number they approach each other and unite, forming streamers which in their turn unite and form bands. No analysis has been obtained of the desmosites, as it was so evident that they contain nothing different from the spilosites.

Adinoles.—Thus far chlorite has been the chief dark constituent of the contact products mentioned, whereas actinolite is

* C was not determined.

either totally absent or else is present merely as an accessory. In the adinoles actinolite is the characteristic constituent. The minor constituents, as a rule, are more uniformly distributed than in the spilosites. However some spots are present and are composed essentially of actinolite. The actinolite is present in sheaf-like growths, lying commonly in an exceedingly fine-grained mass of quartz and albite, with some flakes of chlorite and grains of epidote. The adinole is rendered rather dark by minute black specks which are disseminated through it. In places these are collected in irregular or lenticular heaps. They seem to be carbonaceous matter.

Analysis of Adinole from Mansfield, Michigan.

(By Mr. Geo. Steigor, U. S. G. S.)

SiO_2	74·16
TiO_2	·37
Al_2O_3	11·85
Fe_2O_3	·82
FeO	1·66
MnO	·06
CaO	2·10
BaO	none
MgO	2·10
K_2O	·15
Na_2O	6·57
H_2O at 100°—	·05
H_2O at 100°+	·52
P_2O_5	·08
CO_2	·09
C	·18
Total	100·76

Other varieties of the contact rocks.—There is still another kind of contact rock in which actinolite is the chief dark constituent, and in this the actinolite is mainly collected in bands. This rock thus corresponds to the desmosites (banded chlorite rocks) in structure, though differing from them in mineralogical composition.

The chlorite and actinolite contact rocks may be expected to grade into each other, and such a gradation is shown in one specimen, in which actinolite and chlorite are present in about equal quantity. The actinolite occurs in crystals and sheaves, forming spots; whereas the main mass of the thin section surrounding the spots is formed by chlorite as the dark silicate, associated with feldspar, quartz, and some epidote.

Comparison of analyses.—From previous determinations in other regions it is well known that the adinoles are next to the contact, while the spilosites (and desmosites) are intermediate between them and the clay-slates. The following series of analyses are arranged in the order of approach to the dolerite, as determined by the character of the rocks:

	1.	2.	3.	4.
SiO_2	60·28	52·51	57·77	74·16
TiO_2	·69	1·70	·92	·37
Al_2O_3	22·61	19·00	19·35	11·85
Cr_2O_3		none	none	
Fe_2O_3	2·53	3·31	1·29	·82
FeO	·45	7·19	3·37	1·66
MnO	trace	trace	trace	·06
CaO	·13	1·55	1·71	2·10
BaO	·04	trace	none	none
SrO		trace	trace	
MgO	1·35	3·29	4·35	2·10
K_2O	5·73	·70	·22	·15
Na_2O	·54	6·72	8·22	6·57
Li_2O		trace	none	
H_2O at 100° −	·60	[*] ·34	[*] ·18	·05
H_2O at 100° +	3·62	[†] 3·26	[†] 2·34	·52
P_2O_5	·03	·15	·04	·08
CO_2	none	none	none	·09
S and SO_3		none	none	
C	·97			·18
Cl		none	none	
F		trace	none	
Total	99·57	99·72	99·76	100·76

No. 1, Clay-slate, Spec. No. 32497 L. S. D., U. S. G. S. Analyst Mr. Geo. Steiger.

No. 2, Spilosite, Spec. No. 32861 L. S. D., U. S. G. S. Analyst Dr. H. N. Stokes.

No. 3, Spilosite, Spec. No. 32827 L. S. D., U. S. G. S. Analyst Dr. H. N. Stokes.

No. 4, Adinole, Spec. No. 32465 L. S. D., U. S. G. S. Analyst Mr. Geo. Steiger.

In these analyses the usual increase of silica as the dolerite is approached is at once noticeable, and hand in hand with it goes the diminution in percentage of alumina and iron oxides. The content of water and carbonaceous[‡] matter also suffers diminution, as was to be expected.

The most noteworthy difference between the clay-slate and the contact rocks is shown in the relations of potash and soda. This is well brought out in an examination of analyses Nos. 1

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[*] H_2O at 110°. [†] H_2O above 110°.

[‡] The C in Nos. 2 and 3 was not determined.

and 2. It will be seen that there is only about $\frac{1}{8}$th as much potash in the contact rocks as in the normal clay slate; while, on the contrary, about 12 times as much soda as there was in the slate has been added to the contact rock. This causes a reversal of the relations of the soda and potash, so that, whereas in the clay-slate there is present 10 times as much potash as soda, we find in the contact rock taken as an example very nearly 10 times as much soda as potash.

Comparison of Mineralogical Composition.

It will be sufficient for our present purpose to consider the clay-slate, on the one hand, and the spilosite and adinole on the other. To recapitulate briefly, in the clay-slate we have quartz (clastic), white mica, actinolite, rutile, and an indeterminate interstitial material of finely granular character, discolored by carbonaceous and ferruginous matter. This interstitial material we may consider as that remnant of the original feldspar, quartz, biotite, and iron ore dust in the original clay which was not used in the production of the white mica, actinolite, and rutile now found in the clay-slate. Original chemical differences in the slate are shown by the arrangement of the various materials in bands, certain bands containing a greater quantity of white mica; hence, the conclusion that these were probably richer in alkali than the adjoining bands, which are poor in white mica.

In the spilosite and adinole we find present quartz—but not clastic—white mica, actinolite, and rutile, as in the clay-slate. But in addition there is albite, chlorite, epidote, and biotite. There is nothing in these rocks which shows clastic origin. The original sediment has been completely recrystallized and there remains only the banding to point to the sedimentary origin of the rock. The clastic quartz has been destroyed by solution or aqueous fusion, and has been recrystallized, and now forms a mosaic with the albite. Albite, for whose production some of the silica of the clastic quartz may have been used, is present in the rock in considerable quantity, in contradistinction to its total absence from the slate. The initial quantitative chemical differences existing in the clastic rock are also shown in the recrystallized rock by differences in the mineralogical composition, a large quantity of chlorite, for instance, forming a band adjacent to a band poor in chlorite, thus indicating a richness of the first band in magnesium. The greatest difference existing between the practically unmetamorphosed slate and the contact product is the evidence in this last of complete recrystallization, and the presence of albite in large quantity.

Cause of Chemical and Mineralogical Changes in the Rocks described.

The changes which have taken place in sedimentary rocks as the result of contact with igneous rocks have given rise to a great deal of discussion. The one school, notably represented by the French geologists, contends that there is an actual transfer of material from the igneous rock to the rock intruded with more or less complete resorption of the latter; whereas the other school has maintained that the indisputable metamorphism observed in such cases is due chiefly to the action of the so-called mineralizers. Studies upon a series of contact rocks similar to those here presented have given foundation for the view upheld by Roth,* Zirkel,† and others, that in the case of contact metamorphism produced by basic rocks an actual transference takes place. This view has been recently very strongly advocated by W. Maynard Hutchings,‡ who has described some interesting products, which result from the contact of the Whin Sill, which still further support it.

The very considerable changes which are shown by the above analyses to have taken place in the metamorphism of the slates, especially the change in the amount of silica and soda resulting in the production of albite in large quantity, seem to add weight to the supposition that in such contacts an actual transfer of material, possibly in the form, as has been suggested by others, of a soda silicate, does take place from the basic igneous rock to the intruded slate.

MADISON, WIS.

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* Chemische Geologie, by J. Roth: Berlin, 1890, vol. iii, p. 145.

† Lehrbuch der Petrographie, by F. Zirkel: Leipzig, 2d edit, vol. ii, 1894, p. 722.

‡ Notes on the composition of clay-slates, etc., and on some points in their contact metamorphism, by W. M. Hutchings: Geol. Magazine, vol. i, dec. 4, 1894, p. 75.

An interesting contact rock, with notes on contact metamorphism, by W. M. Hutchings: Geol. Mag, vol. ii, dec. 4, 1895, p. 122-131, 163-169.

ART. XI. — *The Origin of Mammals;*[*] by HENRY F. OSBORN.

SINCE the source of the Mammalian phylum was later than that of the Reptilian phylum in the Permian and possibly Carboniferous, we are sure that it extended at least very far back into the Triassic, and the Triassic was apparently a time of great continental connections and of consequent wide geographical distribution even of land types.

In presenting a phylogenetic chart which traces the ancestry of Mammals to the Upper Permian, I am quite as conscious as the most conservative zoologist present that we are not on sure ground, that this is a castle of cards liable to fall at any moment. Yet such a chart, involving as it does numberless hypotheses, is necessary to set forth certain ideas.

Clearing the way for this discussion, this chart first replaces the general view defended by Huxley in 1880, of a genetic succession between three sub-classes of mammals, which has become a matter of creed with many zoologists. In the last eighteen years not a scintilla of evidence has arisen to show that Placentals are descended from Marsupials, and of late, evidence has been coming in directly against this view. In fact zoo-palæontology now indicates that Marsupials and Placentals are parallel phyla, arising from a common stock, while Monotremes are so different that they may even be considered diphyletic, or derived independently from the Reptilia, as maintained by Mivart among others, and latterly by Seeley.

So far as major classification is affected by this conception, it appears therefore that we must revert to Gill's divisions of 1872, constituting only two sub-classes of Mammals, namely:

A—*Eutheria*	and B—*Prototheria.*
Marsupials, Placentals.	Monotremes.

Marsupials are less primitive than the placental Insectivores, and Marsupials and Placentals are certainly far nearer each other than either are to the Monotremes.

To guide our speculation in the unknown pre-Tertiary period, we may gather certain positive principles from the known evolution of the Tertiary mammalia. First, we know that *adaptive radiation*, characteristic of all vertebrates, and beautifully illustrated among Reptilia, is in a very high degree distinctive of Mammalia, because of their superior plasticity.[†]

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[*] Opening the discussion before the International Congress of Zoologists at Cambridge. (In conjunction with Professor H. G Seeley.)

[†] We know nothing of Africa, whether it enjoyed a radiation of its own or borrowed its fauna from other continents.

There is the (I) *Marsupial radiation of Australia* (Meteutheria)*—now passing its prime, then the (II) *Tertiary Placental radiation of the Northern Hemisphere* (Ceneutheria), and another quite independent (III) *Tertiary placental radiation in South America*, (rendered less pure in course of the Tertiary period by migration from I and II). IV, There is the entirely distinct and archæic *Cretaceous Placental Radiation of the Northern Hemisphere* (Meseutheria), which extends into the Tertiary, and may have given origin to II and III, although as yet we have no direct proof of it.

We mark the fact that the above radiations are all of *ordinal* rank, for the Marsupial radii, although termed families, are adaptively equivalent to several Placental orders.

If we apply these same principles to the Jurassic, we apparently have evidence of a more fundamental (V), *Sub-class radiation of Placentals and Marsupials, and probably Monotremes*, of world-wide distribution. (This involves a controverted question, to which I shall revert, for by some zoologists these animals of the Purbeck Clays, Como Beds, and Stonesfield Slates are considered exclusively Marsupials and Monotremes.) Finally far back in the Perm-Trias we certainly observe (VI), the *Theromorph or Theriodont Reptilian radiation*, spurs of which may have given rise to the Mammalia.

The *focal-types*, or most primitive forms of the radiations, I—IV, *were certainly small, terrestrial, clawed, insectivorous or omnivorous forms.* It is noteworthy that in the evolution of each radiation, so far as we know at present, land types and organs are invariably primitive, and water types and organs are secondary, exactly as we find it among the Reptilia. In fact we have not found a single instance in which a mammal or reptile series is known to be transforming from a water into a land type; it is always the reverse. There is certainly no evidence for a cetoid (Albrecht) stem of the Mammals. Again it is obvious that neither carnivorous nor herbivorous types with highly specialized or reduced teeth and feet can be so central as insectivorous and omnivorous types. In fact the Insectivores among Placentals, and Opossums among Marsupials, are the only animals which have preserved the dental prototype close to that of the Promammal.

The backward convergence of all Tertiary mammalia to a Creodont stem, as indicated in the chart, affords the clearest demonstration of the existence of an earlier insectivorous stem, and it not only accords with the above principles, but we are thus carried a step further to realize that the Creodont ancestor must have been a generalized Insectivore.

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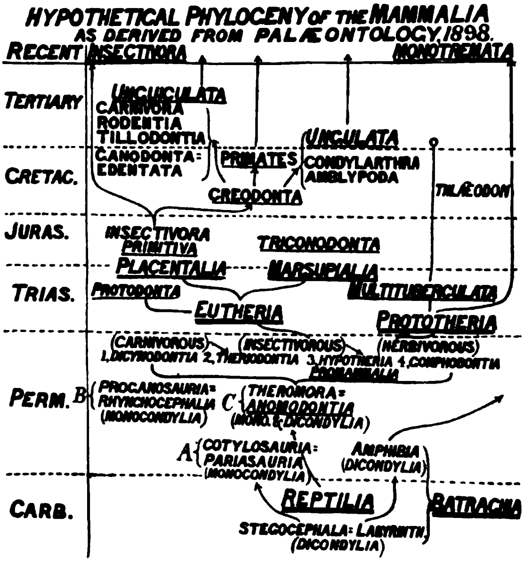
*The Eutheria may embrace the Meteutheria or Marsupials, the Meseutheria or primitive Mesozoic Placentals, the Ceneutheria or Tertiary Placentals.

To reconstruct the ancestral Eutherian skeleton, therefore, we should divest the Creodonta and Insectivora, in their anatomy and development, of all their secondary specializations, and combine all their truly primitive characters. This ideal Eutherian is nearer the pro-Marsupial than we supposed; it has the following chief characters: Head large, body relatively small. Anterior nares terminal, face elongate. Insectivorous or omnivorous habit. Molar teeth pointed, tritubercular. Typical dental succession. Vertebræ with intercentra. Dorsolumbars not exceeding 20. Back arched, tail long and powerful. Scapula and ilium narrow, acuminate. Humerus with powerful deltoid crest, condylar crests and entepicondylar foramen. Femur with three trochanters. Feet plantigrade. Centralia and tibiale. Fore-limb more or less prehensile, elbows everted.



Now the Creodonta are members of that Cretaceous radiation, IV, which we find in full bloom in the Basal Eocene, mingled with the dying group of Multituberculates, which belong to the Jurassic radiation, V.

In the Mid—and Uppermost Jurassic (Stonesfield, Purbeck and Como Beds) however, occur all three types, which theoretically constitute radiation V: first, the *Triconodonts* primitively but typically *Marsupial* in structure; second, the *Insectivora primitiva*, primitively *Placental* in type, insectivorous and without a single Marsupial character either in jaw or teeth; third, the *Multituberculata*, whose sub-class position is now assumed to be *Monotreme.*

Always keeping in mind that our direct evidence here is of the most limited character, since we have neither skulls nor skeletons, only teeth and jaws, we are tempted to hypothetically connect the Creodonta with the Insectivora Primitiva, and to assume that there existed in the Mid-Jurassic, as above stated, the well advanced radiation V of the two sub-classes of EUTHERIA and PROTOTHERIA as defined by Gill.

The problem of the Origin of the Mammals now resolves itself into the connections between these two sub-classes either with the Reptilia or Amphibia, and we turn back to the three contemporary Upper Permian reptile groups:

1. *Pareiasauria or Cotylosauria*, land animals with a solid skull and replete with Stegocephalian or Amphibian characters, certainly the most primitive reptiles.
2. *Proterosauria or Proganosauria*, with an open two-arched skull, specialized reptiles, which have apparent affinities with the Crocodilia, Dinosauria, Rhyncocephalia and Squamata (Dolichosauria, Mosasauria, Lacertilia and Ophidia).
3. *Theriodontia or Theromora* (*Dicynodontia, Cynodontia and Gomphodontia*), with an open, single-arched, skull (as in the Chelonia, Plesiosauria, Icthyosauria and Mammalia).

The Theriodontia as perceived by Owen in 1876, and now fully confirmed by Seeley, are astoundingly mammalian in type. They are essentially quadrupedal, long-limbed, terrestrial reptiles, totally dissimilar from all other reptiles, and standing far away from them. They also present an advanced stage of functional radiation in tooth and skull structure in adaptation to carnivorous, omnivorous and herbivorous habits, to which, when known, their skeletons will probably be found to conform. The shoulder girdle is of Monotreme type; in other features of the skeleton they are strikingly like the ancestral Eutherian, described above. The skull may in fact be reduced to the Eutherian type by the coalescence of the prefrontals, postorbito-frontals and quadrates with the adjacent elements, and by the loss of the ectopterygoids or transverse bones. The teeth are promammalian in formula, and pro-tritubercular or multitubercular in form. The skeleton so far as known is partly Eutherian, partly Monotreme or Prototherian.

Two alternatives at this point present themselves: First: Are the Monotremes directly derived from such a type as these Theriodonts, leaving an independent derivation for the Eutherian or Marsupio-placental stock, as has been suggested by Seeley? Second: Must we set aside the Theriodonts for an Amphibian stem form on account of the numerous Amphibian resemblances which Hubrecht and others find in the development and anatomy of the lower Mammalia?

The first question is now unanswerable, although at present the evidence that the Mammalia are diphyletic is certainly considerable. Second, the investigation of the placental ovum rises to extreme importance; if the Eutherian ovum is of Amphibian type, the Mammalia are certainly diphyletic, for the Monotreme ovum is certainly of reptilian type. This point may be met by supposing that at the time the Marsupio-placentals were given off, the Theriodontia conserved a number of Amphibian characters, which were at the time or subsequently lost.

The problem of most immediate concern, therefore, is whether the Theriodontia are actually the long-sought Promammalia of Hæckel, Hypotheria of Huxley or Sauromammalia of Baur, or whether they present a fresh instance of extensive parallelism due to the assumption of habits analogous to those of Mammalia. Professor Seeley has just presented the latter view,* and it is certainly true that none of the known Theriodontia fill the characters outlined above as those we must look for in the Promammal or Eutherian stem, for they are all too large and too specialized.

There are however grounds for the more sanguine former view, that the Theriodontia are the Hypotheria or Promammalia, because it appears that *within the order may well have existed some small insectivorous types, far less specialized in tooth structure than either the carnivorous Cynodonts or herbivorous Gomphodonts, as one of those conservative spurs of adaptive radiation which form the focus of a new progressive type.*

The problem will therefore be settled by additional discovery and knowledge of the structure of the diverse types which undoubtedly composed this remarkable group.

NOTE. We can happily preserve that part of Huxley's speculation upon the origin of the Mammals which pictured the Insectivora as nearest the ancestral type. The Amphibian (or Stegocephalian) origin of the Mammalia which he defended, is wholly set aside, if the view here taken is correct, for the Theriodontia are certainly not Amphibia in any sense.

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* "Anomodonts are not the parents of Mammals, but a collateral and closely related group. The common parent of both may be sought in rocks older than Permian, perhaps in Silurian or Devonian strata." Printed abstract of Professor Seeley's argument, p. 3.

ART. XII.—*On the Chemical Composition of Tourmaline;* by S. L. PENFIELD and H. W. FOOTE.

INTRODUCTION AND HISTORICAL.—There is probably no common mineral whose chemical composition has proved more perplexing and been so little understood as tourmaline. Some reasons for this are, first, that the mineral presents certain peculiarities in chemical composition of an unusual nature; second, the analysis of tourmaline has been one of the difficult problems of analytical chemistry, hence reliable data for the calculation of the formula have not been easily obtained; and, lastly, although good analyses have been made, the results have not been thoroughly relied upon, nor have they been interpreted to the best advantage. The present investigation was undertaken, therefore, with the hope that by making a few analyses with the utmost possible care on tourmalines of exceptional purity, it would be possible to find a satisfactory explanation of the chemical composition of this interesting mineral.

In order to appreciate the problem in hand, it will be necessary to review briefly the work and the results of previous investigators.

The analyses of Vauquelin and Klaproth, made in the early part of this century, were naturally defective, because at the time they were made, lithium was unknown, it had not been discovered that tourmaline contained boron, and analytical methods were not perfected.

In 1818 the presence of boron was detected by Lampardius,* and in the same year Arfvedson† discovered the new alkali metal lithium, and showed its presence in spodumene, petalite and tourmaline.

In 1827 Gmelin‡ published analyses of ten varieties of tourmaline, but his results led to no satisfactory formula, although the essential constituents of the mineral, with the exception of the boric oxide, were determined with a considerable degree of accuracy.

In 1845 Hermann§ published the results of four analyses of tourmaline from Russian localities. He proved conclusively that the iron was ferrous, and not ferric as considered by previous investigators. Boric oxide was not directly determined, but estimated by difference, and the results compare favorably with the direct determinations made by our present methods.

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* Ann. d. Phys. u. Chem., xxx, p. 107.

† Schweiger's Jour. d. Chem. u. Phys., xxii, p. 111.

‡ Pogg. Ann., ix, p. 127.

§ Journal für prakt. Chem., xxxv, p. 232.

He was the first to point out that silica and boric oxide are present in the definite molecular proportion 4 : 1. He erroneously decided that tourmaline contained carbon dioxide, the reasons being as follows: It was generally believed at that time that the mineral contained no water, as stated by Hermann "*die Turmaline keine Spur davon enthalten*," and it is true that when fragments are tested by the usual method of heating to redness in a closed tube no water is obtained. It is only when the material is heated *intensely*, best as fine powder, that hydroxyl is decomposed and water given off. When Hermann dissolved fragments in a borax bead he observed that a gas was evolved, and, since it was believed that this could not be water vapor, he supposed that it must be carbon dioxide. Pains were taken to fuse some of the mineral in a tube with borax, and to conduct the gas into lime water, by which treatment a precipitate was obtained which effervesced with acids, but it is safe to assume that the carbon dioxide thus detected was derived from improperly purified air and not from the mineral.

In 1850 Rammelsberg* published the results of the analyses of thirty varieties of tourmaline. The execution of such a large number of analyses must be regarded as a very great undertaking, since at that time gas and many facilities of our modern laboratories were not available, and many methods of analysis were not perfected. Special evidence is given that great care was taken in the selection of material for analysis and in the analytical methods, which appear to have been well chosen and reliable in character. The analyses, however, were defective in several important particulars. Thus the iron was regarded chiefly as ferric. Believing, like Hermann, that tourmaline contained no water, and having detected the presence of fluorine in some varieties of the mineral, he supposed that the considerable loss on ignition which occurred was due to the volatilization of silicon fluoride, and from this loss he estimated fluorine to be present in amounts varying from 1·30 to 2·51 per cent. Direct determinations of boric oxide were made in three cases only, and in the remaining analyses this important constituent was estimated by difference. Although the analyses led to no satisfactory formula, they indicated certain prominent characteristics of the mineral, namely, the great variation in the relative amounts of aluminium, iron, magnesium and alkalies, and the nearly uniform amounts of silica and boric oxide.

Fully realizing certain defects in his earlier analyses, Rammelsberg† published in 1870 a revision of his former paper.

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* Ann. der Phys. u. Chem., lxxx, p. 449 and lxxxi, p. 1.

† Ann. der Phys. u. Chem., ccxv, pp. 379 and 547.

At this time it was shown that all varieties of tourmaline contained chemically combined water, and the amount of water was estimated from the earlier determinations of the loss on ignition after making certain corrections for volatilization of silicon fluoride. He found that the iron was chiefly if not wholly ferrous, and recalculated accordingly his earlier results. Six direct determinations of boric oxide were made, and it is pointed out that these amounts correspond closely with the indirect determinations by difference. As a result of the revision, Rammelsberg reached the conclusion that all tourmalines are derived from the acid H_6SiO_5. In this he considered the hydrogen atoms to be replaced by metals of different valences, or, in other words, he regarded tourmaline as composed of a mixture of the following molecules:

R'_6SiO_5 $R' =$ Na, K, Li and H.
R''_3SiO_5 $R'' =$ Fe, Mg, Mn and Ca.
R'''_2SiO_5 $R''' =$ Al and B.

Furthermore he decided that certain varieties correspond closely to the special formulas

$$\text{I.}\left\{\begin{array}{l} R'_3Al_2BSi_2O_{10} \\ R''_3Al_4B_2Si_4O_{20} \end{array}\right. \quad \text{and} \quad \text{II.}\left\{\begin{array}{l} R'_6Al_{12}B_4Si_9O_{45} \\ R''_3Al_{12}B_4Si_9O_{45} \end{array}\right.$$

while he regarded others as mixtures of these two molecules. By substituting hydrogen atoms for the metals and boron of these special formulas, the acids become respectively $H_{24}Si_4O_{20}$ and $H_{54}Si_9O_{45}$, both of which are multiples of H_6SiO_5. He concluded that the SiO_2 and B_2O_3 are not present in a definite molecular proportion, but that boron plays the part of a metal and is isomorphous with aluminium.

In 1888 Riggs* published the results of twenty analyses of various types of tourmaline from American localities. The analyses were executed in the laboratory of the U. S. Geological Survey at Washington, and bear every evidence of being made with the precision and care characteristic of the analytical work of that laboratory. Boric oxide, water and ferrous oxide were determined directly by reliable methods, and a high degree of accuracy is claimed for the analyses. A careful description of the quality of the material analyzed is not given, and although it is to be supposed that great care was taken in its selection, the following statement has left this in doubt: "The analyses do not represent ideal compounds, but are made of material more or less impure . . . . " Riggs concludes that the analyses give "as a general tourmaline formula the simple boro-orthosilicate $R_9BO_2 2SiO_4$ " which is expressed graphically as follows:

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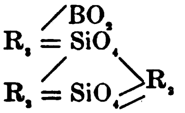
* This Journal, III, xxxv, p. 35.



He supposes R to include H, Li, Na, K, Ca, Mg, Fe, Al and small amounts of the Al=O or possibly Al·OH radicals. It may here be stated that the foregoing formula is identical in type with the special formula $R'_9Al_3BSi_2O_{10}$ ($H_9BSi_2O_{10}$) of Rammelsberg, and considering boron as replacing hydrogen like a metal the silicic acid from which the formula is derived becomes $H_{12}Si_2O_{10}$ or H_6SiO_5. Riggs further states that, owing to slight variations, the ratios give nearly the "equally simple general formula $R_{10}BO_22SiO_4$," stating that "between these two views there are at present no means at hand of deciding." It would seem, however, that the last formula is impossible, for, considering hydrogen atoms as replacing R_{10}, the acid can not be split up like other oxygen acids into silicic and boracic anhydrides and water. There are also given the following special formulas for three pronounced types of tourmaline:

I. Lithia tour.	$12SiO_2$, $3B_2O_3$, $4H_2O$, $8Al_2O_3$, $2(NaLi)_2O$.
II. Iron tour.	$12SiO_2$, $3B_2O_3$, $4H_2O$, $7Al_2O_3$, $4FeO$, Na_2O.
III. Mg tour.	$12SiO_2$, $3B_2O_3$, $4H_2O$, $5Al_2O_3$, $\frac{28}{3}MgO$, $\frac{2}{3}Na_2O$.

By substituting hydrogen atoms for the metals in these special formulas we obtain:

I. and II.	$H_{60}B_6Si_{12}O_{63}$ or $H_{20}B_2Si_4O_{21}$.
III.	$H_{58}B_6Si_{12}O_{62}$ or $H_{19\frac{1}{3}}B_2Si_4O_{20\frac{2}{3}}$.

Soon after the appearance of Riggs' article, Wülfing* recalculated the results of these twenty analyses and concluded that all tourmalines may be regarded as isomorphous mixtures of two aluminium silicates, "*Alumosilicate*," of the following composition.

I. Alkali tourmaline	$12SiO_2 . 3B_2O_3 . 8Al_2O_3 . 2Na_2O . 4H_2O$,
II. Magnesia tourmaline	$12SiO_2 . 3B_2O_3 . 5Al_2O_3 . 12MgO . 3H_2O$.

In these formulas it is assumed that the isomorphous elements K and Li replace the Na; Fe‴ the Al; and Fe″, Mn and Ca the Mg. By substituting hydrogen atoms for the metals in the foregoing formulas it is found that they both are derivatives of the same acid, $H_{60}B_6Si_{12}O_{63}$ or $H_{20}B_2Si_4O_{21}$. The conclusions derived by Wülfing are that, although in most cases the results of the analyses agree with the percentage values calculated from his formulas, the agreement is not always satisfactory. This he ascribes to the possible need of a third formula; to possible inaccuracies in the difficult ferrous iron determinations; and in part to the fact, as stated by Riggs, that "the analyses do not represent ideal compounds. . . ." He therefore considers it necessary that further analyses of more carefully selected material should be made.

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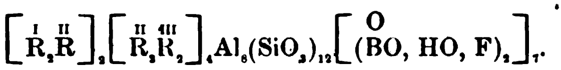
* Mineralogische und petrographische Mittheilungen, x, p. 161.

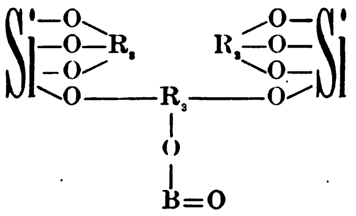
At about this time also Scharizer* published analyses of three varieties of tourmaline from Schüttenhofen, Bohemia, and discussed his results in connection with the analyses of Riggs. His final conclusion is that, with the exception of the green varieties, tourmalines possess a chemical constitution which can be expressed by the general formula



$$\left[\overset{\mathrm{I}}{R}_2\overset{\mathrm{II}}{R}\right]_2\left[\overset{\mathrm{II}}{R}_3\overset{\mathrm{III}}{R}_2\right]_4 Al_6(SiO_5)_{12}\left[\begin{matrix}O\\(BO, HO, F)_2\end{matrix}\right]_7.$$

This formula is certainly difficult to comprehend, and, if we understand it correctly, the univalent radicals BO and HO are isomorphous with fluorine, and these constituents, taken twice, can replace oxygen.

In 1889 Jannasch and Kalb† published the results of nine tourmaline analyses, in which the water and boron were determined directly. These investigators derived from their analyses the general formula $R_9 . BO_2 . (SiO_4)_2$, for which the following structural formula was proposed:



This formula, $R_9 . BO_2 . (SiO_4)_2$, is identical with the one proposed by Riggs, and essentially like the special formula $R'_3Al_2BSi_2O_{10}$ of Rammelsberg. The following special formulas are also given:

I. Li tour.	$24SiO_2 . 6B_2O_3 . 15Al_2O_3 . 4FeO . 4(Li_2O, Na_2O) . 7H_2O$
II. Fe tour.	$24SiO_4 . 6B_2O_3 . 14Al_2O_3 . 9FeO . 2Na_2O . 7H_2O$
III. Fe-Mg tour.	$24SiO_2 . 6B_2O_3 . 13Al_2O_3 12MgO . 2Na_2O . 7H_2O$

These special formulas in their general type are similar to those proposed by Riggs. By substituting hydrogen atoms for the metals they all reduce to one and the same acid, $H_{120}B_{12}Si_{24}O_{126}$ or $H_{20}B_2Si_4O_{21}$.

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* Zeitschr. für Kryst., xv, p. 343.

† Berichte der deutschen chemischen Gesellschaft, vol. xxii, p. 216. Also Inaugural Dissertation, Geo. W. Kalb, Göttingen.

There is evidence that Jannasch does not place great confidence in the foregoing formulas, for in Hintze's Mineralogy* the composition is expressed as follows:

I. Lithia tourmaline $Si_{12}O_{63}B_6Al_{16}(Na, Li)_4H_7$
II. Iron tourmaline $Si_{12}O_{67\frac{1}{2}}B_6Al_{14}Fe_9Na_2H_7$
III. Magnesia tourmaline $Si_{12}O_{69}B_6Al_{13}Mg_{12}Na_2H_7$

These formulas are essentially different from the ones first proposed, which may readily be seen by substituting hydrogen atoms for the metals and comparing the resulting acids, as follows:

I. $H_{56}B_6Si_{12}O_{63}$ or $H_{18\frac{2}{3}}B_2Si_4O_{21}$
II. $H_{69}B_2Si_{12}O_{67\frac{1}{2}}$ or $H_{23}B_2Si_4O_{22\frac{1}{2}}$
III. $H_{72}B_2S_{12}O_{69}$ or $H_{24}B_2Si_4O_{23}$

Soon after the appearance of the articles of Riggs and of Jannasch and Kalb, the results of their analyses were recalculated by Goldschmidt,† and the conclusion was reached that tourmaline may be regarded as containing the two following molecules:

I. Alkali tourmaline $R'_{32}R'''_{56}Si_{31}O_{162}$
II. Magnesia tourmaline $R'_{20}R''_{24}R'''_{44}Si_{31}O_{162}$

These formulas are both derived from an acid $H_{200}Si_{31}O_{162}$ or $H_{6.46}SiO_{5.23}$.

In 1893 Rheineck,‡ after calculating the results of the many tourmaline analyses, concluded that the composition of all tourmalines may be expressed by formulas of the following type, in which Al_4 appears as a constant:

I. Alkali tourmaline $Al_4Si_3BH_3O_{15}$
II. Alkali tourmaline $Al_4Si_3B_2H_4O_{17}$
III. Magnesia tourmaline $Al_4Si_5B_2M_4H_4O_{25}$, etc.

M represents the bivalent metals Fe, Mn, Mg and Ca. H includes Na, Li and K. Among the numerous examples he stated that the composition of the black tourmaline from Pierrepont, N. Y., may be represented by either of the following expressions:

$$\left\{\begin{array}{l} 114\ Al_4Si_5B_2M_4H_4O_{25} \\ \ \ 10\ Al_4Si_3B_6O_{25} \end{array}\right. \quad \text{or} \quad \left\{\begin{array}{l} 10\ Al_4Si_3B_2H_6O_{18} \\ 93\ Al_4Si_5B_2M_4H_4O_{25} \\ 21\ Al_4Si_5B_4M_4O_{26} \end{array}\right.$$

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* Vol. ii. p. 311 (communication from manuscript by Jannasch).

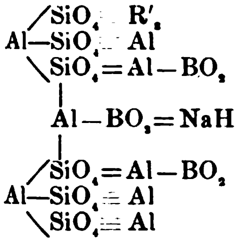
† Zeitschr. für Kryst, xvii, pp. 52 and 61.

‡ Zeitschr. für Kryst., xxii, p. 52.

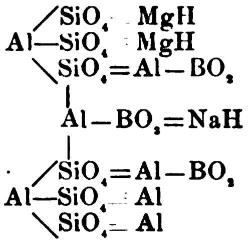
By substituting hydrogen atoms for the metals in these expressions, and multiplying by the factors, 114 and 10 in the one case; and 10, 93 and 21 in the other, the acids become $H_{2014}B_{285}Si_{600}O_{3100}$ and $H_{2832}B_{290}Si_{600}O_{3051}$, or, when simplified, $H_{13.4}B_{1.9}Si_4O_{20.6}$ and $H_{18.9}B_{1.9}Si_4O_{20.3}$. The improbable nature of such acids is evident. In the opening paragraph of his article Rheineck stated that the obscure and complex chemical relations of this mineral have necessitated a series of speculations and calculations extending somewhat interruptedly over a period of many years, in order to arrive at results such as those embodied in the foregoing formulas.

In 1895 Clarke* discussed the constitution of tourmaline and proposed the following formulas:

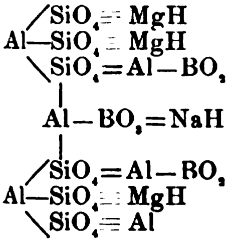
1.



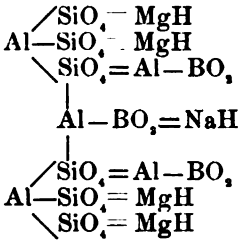
2.



3.



4.



Clarke assumes variations from these formulas in that Fe‴ and Cr can replace the Al; Fe″ and Mn the Mg; Ca the NaH; and small amounts of F the BO_2. Proof of a constitution corresponding to the formulas cannot of course be expected, but it is doubtful whether aluminium could exercise such varied functions as the formulas indicate. The grounds for believing that fluorine can replace BO_2 are not stated. The acid from which all these formulas are derived is $H_{20}B_3Si_6O_{31}$ or $H_{13\frac{1}{3}}B_2Si_4O_{20\frac{2}{3}}$.

Lastly Groth† has adopted the formula of Jannasch $[SiO_4]_2 . BO_2 . R'_9$, but interprets it as follows:

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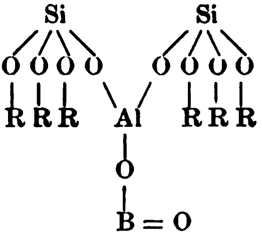
* Bulletin of the U. S. Geological Survey, No. 125, p. 56.

† Tabellarische Uebersicht der Mineralien, 4te Auflage, 1898, p. 117.



or $[SiO_4]_2[AlO\,.\,BO]([AlO]_3, Mg, Fe, Na_2, Li_2, H_2)$.

That the univalent radical [AlO] can replace R′ does not appear in the original article of Jannasch, and it makes a decided difference whether three R's are replaced by one atom of Al or by three [AlO] radicals. The latter assumption implies a basic character which tourmaline does not possess.

We have thus reviewed the work already done in order to show the difficulties which this problem has presented. It is, however, interesting to note how closely different investigators come to one type of acid from which all varieties of tourmaline are derived. For the sake of comparison these acids have been reduced to four silicon atoms, and are given below, both as borosilicic acids and with the boron replaced by hydrogen.

Rammelsberg	$H_{18}B_2Si_4O_{20}$	or	$H_{24}Si_4O_{20}=H_6SiO_5$
	$H_{18\cdot66}B_{1\cdot77}Si_4O_{20}$	or	$H_{24}Si_4O_{20}$
Riggs	$H_{18}B_2Si_4O_{20}$	or	$H_{24}Si_4O_{20}$
	$H_{20}B_2Si_4O_{20}$	or	$H_{26}Si_4O_{20}$ (Irrational)
	$H_{20}B_2Si_4O_{21}$	or	$H_{26}Si_4O_{21}$
	$H_{19\cdot33}B_2Si_4O_{20\cdot66}$	or	$H_{25\cdot33}Si_4O_{20\cdot66}$
Jannasch and Kalb	$H_{18}B_2Si_4O_{20}$	or	$H_{24}Si_4O_{21}$
	$H_{20}B_2Si_4O_{21}$	or	$H_{26}Si_4O_{20}$
Wülfing	$H_{20}B_2Si_4O_{21}$	or	$H_{26}Si_4O_{21}$
Goldschmidt			$H_{25\cdot8}Si_4O_{20\cdot9}$
Rheineck	$H_{19\cdot0}B_{1\cdot9}Si_4O_{20\cdot6}$	or	$H_{24\cdot7}Si_4O_{20\cdot6}$ (Irrational)
	$H_{18\cdot9}B_{1\cdot9}Si_4O_{20\cdot3}$	or	$H_{24\cdot6}Si_4O_{20\cdot3}$ etc.
Clarke	$H_{19\cdot33}B_2Si_4O_{20\cdot66}$	or	$H_{25\cdot33}Si_4O_{20\cdot66}$

NEW ANALYSES.

Method of analysis.—The present investigation was undertaken with the expectation that for the solution of the problem in hand it would probably not be necessary to make a long series of analyses but rather *exceedingly accurate* analyses of a few carefully selected types of tourmaline. We therefore prefaced our work by a careful study of those features of the tourmaline analysis, which have proved most difficult. The method proposed by Gooch* of distilling off the boron with methyl alcohol and weighing it as calcium borate is very exact, but its application to an insoluble silicate, especially one containing fluorine, needed careful study. Mixtures were accordingly made of silicates to which weighed quantities of borax and fluorite were added and the following conditions were determined, which yielded the most accurate boron determinations. The mineral was fused with from four to five parts of sodium carbonate, the fusion extracted with water, and, without filtering, an excess of ammonium carbonate was added. The insoluble residue and the precipitate were filtered off, the filtrate concentrated, acidified slightly with nitric acid and distilled with methyl alcohol. The residue from the sodium carbonate fusion together with the precipitate produced by the ammonium carbonate was fused again with sodium carbonate, treated with water, filtered and distilled with methyl alcohol after acidifying with nitric acid. About one half of one per cent of boric oxide was obtained from the second treatment, and in no case did we succeed in obtaining an exact determination of the boric oxide without repeating the fusion. The weighed mixture of calcium borate and oxide was in all cases found to contain a small amount of fluorine. It was therefore dissolved in hydrochloric acid, and part of the lime together with calcium fluoride was precipitated with sodium carbonate. The precipitate was ignited, treated with acetic acid and the resulting calcium fluoride weighed. The amount of fluorine thus found never amounted to over 0·20 per cent.

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* Amer. Chem. Jour., ix, p. 23.

Fluorine was determined by the modified Berzelius method described by Penfield and Minor.*

Water was determined by fusing the mineral with sodium carbonate in a combustion tube and collecting the water in a weighed tube containing sulphuric acid, a method which has been thoroughly tested and is known to give reliable results.†

For the determination of the bases the mineral was decomposed by fusion with sodium carbonate and the silica separated as usual. It was found by experiment that the amount of silica volatilized by the small amount of fluorine in the mineral could practically be neglected. In one variety of tourmaline two determinations of silica made by the Berzelius method of fusing the mineral and a weighed amount of silica with sodium carbonate, and separating the silica with ammonium carbonate and an ammoniacal solution of zinc oxide, gave 36·69 and 36·76 per cent, while determinations by the ordinary method gave 36·75 and 36·73 per cent. A similar conclusion, that when the amount of fluorine is small it is not necessary to separate the silica by the Berzelius method, was also reached by Riggs.

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* This Journal, III, xlvii, 1894, p. 387.

† This Journal, III, xlviii, 1894, p. 31.

The filtrate from the silica was evaporated to dryness, moistened with hydrochloric acid and repeatedly evaporated with methyl alcohol to remove all possibilities of boric oxide being precipitated with the bases and thus increasing their weight.

For the determination of the alkalies the Smith fusion was employed and, after removal of ammonium salts, the residue was treated with acid and methyl alcohol and evaporated to remove any borate that might possibly be present. Lithium was separated by the Gooch method of boiling with amyl alcohol,* and was finally weighed as sulphate.

It was proved by careful qualitative tests † that the iron was ferrous, and that, at the most, not more than traces of ferric iron could be present. This statement holds good not only for the varieties analyzed, but for all the varieties of black tourmaline which were accessible to us.

Selection and preparation of material.—One of the varieties selected for analysis was the white or colorless tourmaline from De Kalb, St. Lawrence Co., New York. This was chosen because according to the analysis of Riggs it represented almost the extreme type of a magnesia tourmaline, and, containing almost no iron, there could be no appreciable error from a failure to estimate that constituent correctly. The material was derived in part from a specimen in the Brush Collection and in part from specimens collected by one of us (Penfield) while connected with the U. S. Geological Survey. The clear, colorless, glassy material was most carefully selected with the aid of a lens, ground and sifted to a uniform grain, and suspended in methylene iodide. The specific gravity was uniform, and the portion used for the analysis floated at 3·065 and sank at 3·033. As an additional precaution the grains were treated with a mixture of hydrochloric and hydrofluoric acids, which have almost no action even on finely pulverized tourmaline, in order to remove any possible traces of adhering calcite, tremolite or pyroxene, although these were not seen nor believed to be present. It may be stated concerning the final product that probably it was as pure as it is possible to get a mineral substance.

Another variety selected for analysis was from the feldspar quarries at Haddam Neck on the Connecticut River. Wonderful tourmalines have recently been obtained from this locality, and they are already well know to most collectors. We are indebted for our supply of material to Mr. Ernest Schernikow of New York, who generously placed at our disposal an almost unlimited supply of crystals of gem quality. We selected small prisms, 2 to 4^{mm} in diameter, of a uniform rather pale green color. They were of ideal purity, perfectly transparent and without flaws. Any traces of foreign material that might possibly be adhering to their outer surfaces were removed by treating them for a considerable time with hydrofluoric acid. The specific gravity, taken with the chemical balance, was found to be 3·089.

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* Amer. Chem. Jour., ix, p. 33.

† See note, p. 124.

We were prepared to extend our investigation by analyzing other varieties, but having completed the above mentioned two and finding that the results corresponded with those of other investigators, it was decided that the data which would be derived from further analyses would probably add very little to the knowledge which we already possess.

The results of the analyses are as follows:

COLORLESS TOURMALINE, DE KALB, N. Y.

	I.	II.	Average.				Riggs.
SiO_2	36·69	36·76	36·72÷60=		·612	4·00	36·88
TiO_2	·06	·05	·05				·12
B_2O_3	10·86	10·77	10·81÷70=		·154	1·01	10·58
Al_2O_3	29·75	29·61	29·68÷17=	1·741			28·87
FeO	·23	·21	·22÷36=	·006			·52
MgO	14·91	14·92	14·92÷20=	·746			14·53
CaO	3·47	3·50	3·49÷28=	·125	3·042	19·90	3·70
Na_2O	1·29	1·23	1·26÷31=	·040			1·39
K_2O	·07	·03	·05÷47=	·002			·18
H_2O	2·98	....	2·98÷ 9=	·331			3·56
F	·92	·95	·93÷19=	·049			·50
			101·11				100·83
O equivalent to F			·39				·21
			100·72				100·62

GREEN TOURMALINE, HADDAM NECK, CONN.

	I.	II.	Average.				Brazil. Riggs.
SiO_2	36·87	37·05	36·96÷60 =		·616	4·00	37·39
TiO_2	·03	·03	·03				?
B_2O_3	11·09	10·92	11·00÷70 =		·157	1·02	10·29
Al_2O_3	39·53	39·59	39·56÷17 =	2·327			39·65
FeO	2·12	2·15	2·14÷36 =	·059			*2·42
MnO	1·96	2·04	2·00÷35·5=	·056			1·47
MgO	·15	·15	·15÷20 =	·008			none
CaO	1·32	1·25	1·28÷28 =	·046	3·078	19·98	·49
Na_2O	2·13	2·06	2·10÷31 =	·068			†2·67
Li_2O	1·65	1·63	1·64÷15 =	·110			1·71
H_2O	3·14	3·06	3·10÷ 9 =	·344			3·63
F	1·09	1·17	1·13÷19 =	·060			·32
			101·09				100·04
O equivalent to F			·48				·13
			100·61				99·91

* Includes 0·15 per cent. Fe_2O_3.

† Includes 0·25 per cent. K_2O.

On treating the analyses according to the customary method of deriving a formula (dividing each constituent by its molecular weight and finding the ratio of the quotients) it was found that although the SiO_2 and B_2O_3 were present in the proportion of 4:1, no definite relation could be detected between the silica, the different kinds of oxides, and the water. It was decided, therefore, to determine the relative number of hydrogen atoms equivalent to the metals and thus learn the acid from which tourmaline is derived. This was readily accomplished by dividing the constituents by appropriate fractions of their molecular weights; for example, since the aluminium atoms in Al_2O_3 replace six hydrogens, the quantity of Al_2O_3 was divided by one-sixth of its molecular weight, the FeO by one half of its molecular weight, etc. Since fluorine is regarded as playing the same role as hydroxyl, its ratio was added directly to that of the hydrogen. The result of this treatment is very satisfactory. The first analysis gives the ratio of $SiO_2:B_2O_3:H = 4:1:19·90$, and the second 4:1·02: 19·98. Both ratios approximate so closely to 4:1:20 that there can be no reasonable doubt that the acid from which these tourmalines are derived is $H_{20}B_2Si_4O_{21}$. This formula may seem at first somewhat complex, but it is not especially so for a boro-silicic acid. It can not be simplified by division, and it is based upon the very best kind of evidence, namely, the close approximation to rational numbers of the two ratios, which are derived from widely separated types of tourmaline.

Before discussing the possible constitution of this acid, it will be shown to what extent the analyses of other investigators confirm the results obtained by us.

REVIEW OF RAMMELSBERG'S ANALYSES.—The analyses appear with certain variations in his different publications, and the results which will be discussed here are given in his *Mineralchemie*, 1875. These are quoted in the sixth edition of Dana's Mineralogy, and where there is occasion to refer to individual analyses they will be designated by the numbers assigned to them in the latter work. The same plan also will be adopted for the analyses of Riggs, Jannasch and Kalb and others. Thirty-five analyses are given by Rammelsberg, of which No. 34 is not complete.

Adopting the same method of calculation as applied to our own analyses, and using one-fourth of the silica as unity, the ratios of $SiO_2:B_2O_3$ were found to vary between 4:1·21 and 4:0·71, and the ratios of SiO_2 to the total hydrogen atoms between 4:16·5 and 4:19·7. The result of grouping the ratios of the hydrogen atoms is as follows:

Limits of variation,	16·5—17·5	17·5—18·5	18·5—19·5	19·5—19·7
Number of analyses,	8	12	12	2

The ratios of SiO_2 to the total hydrogen atoms show a wide variation, and the hydrogens for the most part fall far below 20, which is required by the new formula. Rammelsberg, however, claims that boron plays the part of a metal, replacing aluminium, and that all tourmalines are derivatives of an acid H_6SiO_5 or $H_{24}Si_4O_{20}$. Replacing, therefore, the boron by hydrogens (B_2O_3 is equivalent to $3H_2O$), it is found that the ratios of SiO_2 to the total hydrogens then vary from 4 : 21·9 to 4 : 25·1. The result of grouping the ratios is as follows:

Limits of variation,	21·9—22·5	22·5—23·5	23·5—24·5	24·5—25·1
Number of analyses,	3	10	17	4

The ratio of SiO_2 to the total hydrogens demanded by Rammelsberg's formula is 4 : 24, and in only seventeen, or one-half, of the analyses are the ratios 24 ± 0·5, while they are reasonably sharp, 24 ± 0·2, in only seven cases. It would seem therefore that owing to certain defects the analyses fail to give decisive results. The ratios do not satisfactorily support Rammelsberg's formula nor the one which we have proposed. In his latest publications* Rammelsberg claims great accuracy both for his analyses and for the analytical methods which he employed, and in justice to him it does not seem right to ignore his results without endeavoring to discover the possible defects of the analyses and the influences exerted by them upon the ratios. In the first place, it is believed, for the following reasons, that his silica determinations are too high: it is presumable that facilities were not at hand for producing the intense heat necessary for expelling the last traces of water from the silica; there is no statement that the silica was tested as to its purity by volatilization with hydrofluoric acid; and, lastly, a little silica might have been derived from glass beakers and even from the distilled water, provided it was kept in glass bottles or carboys. It is certain that the water determinations are too low, and this is admitted by Rammelsberg. It is well known that when a silicate containing fluorine and hydroxyl is heated some hydrofluoric acid is liberated, and if the experiment is tried in a closed tube the glass is etched, while probably the mineral also is attacked with the formation of silicon fluoride. Rammelsberg,† however, points out that only a portion of the fluorine is thus expelled, and since the amount of fluorine in tourmaline is small, the loss on ignition should give a fair estimate of the amount of water which the mineral contains. Loss on ignition seems to have been very carefully determined by Rammelsberg, and in those analyses in which fluorine is estimated the water is given as equal to the loss on ignition *less either the fluorine or the silicon fluoride equivalent to it*, while when no fluorine was determined a quantity is *assumed*, usually one-third to one-half of one per cent, and this quantity or the silicon fluoride equivalent to it is deducted from the loss on ignition. In the latter case the *assumed* quantity of fluorine never appears in the results as a constituent of the mineral. Again, no account seems to have been taken of the fact that on prolonged ignition the ferrous iron may become oxidized to ferric, thus causing the water determinations to be too low. In this connection it is interesting to refer to some results obtained by Riggs, who has given with many of his analyses both the loss on ignition and the direct water determinations. When much ferrous oxide is present the loss on ignition is less than the water, but when this loss is increased by an amount equivalent to the oxygen which the iron present can take up in changing from ferrous to ferric oxide, the results become almost equal. The results, in fact, would almost do for duplicate determinations, as shown below:

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* Berlin Akademie, 1890. Mineralchemie, Zweites Supplement, 1895.

† Mineral Chemie, Zweites Supplement, p. 284.

Number	36	37	38	41	42	44	45	46	47	48	49	50	51
Increase of O_	·03	·06	·15	·35	·72	1·34	1·58	1·52	1·32	·94	·91	·91	·42
Loss on ign...	4·35	4·10	4·09	3·62	3·31	2·30	2·17	2·19	2·41	2·88	2·86	2·69	3·59
	4·38	4·16	4·24	3·97	4·03	3·64	3·75	3·71	3·73	3·82	3·77	3·60	4·01
H_2O direct ...	4·26	3·90	4·16	3·64	3·49	3·69	3·62	3·49	3·62	3·63	3·60	3·34	3·79

We cannot agree with Rammelsberg that the method adopted by Riggs for determining water directly gives too high results, for it has been abundantly proved that when properly executed it gives exceedingly accurate ones. It is safe to assume, therefore, that if the determinations of the loss on ignition as given by Rammelsberg are corrected for the oxidation of the iron, the results will furnish fair estimates of the percentages of water.

Accepting as an established fact that SiO_2 and B_2O_3 are always present in tourmaline in the proportion 4:1, Rammelsberg's results may be modified by correcting the water determinations and estimating both SiO_2 and B_2O_3 by difference, thus distributing the errors of analyses upon two constituents, rather than upon the B_2O_3 alone. Below are given the results of applying this method of correction to seven of Rammelsberg's analyses made upon varieties of tourmaline which have subsequently been investigated by either Riggs or Jannasch and Kalb. There are also given for comparison the analyses of the other investigators and Rammelsberg's figures for SiO_2, H_2O and loss on ignition.

		Gouverneur, N.Y.,		Monroe, Conn.,		Haddam, Conn.,		Snarum,	
		Brown.		Brownish-Black.		Black.		Black.	
		Rm. 1.	Rgs. 53.*	Rm. 7.	Rgs. 51.	Rm. 11.	Rgs. 47.	Rm. 12.	J. & C. 56.
	TiO_2		1·19		1·61		·57		1·10
Corrected.	SiO_2	[35·76]	37·39	[36·40]	36·41	[34·75]	34·95	[34·56]	35·64
Corrected.	B_2O_3	[10·43]	10·73	[10·61]	9·65	[10·14	9·92	[10·08]	9·93
	Al_2O_3	31·32	27·79	31·18	31·27	30·87	31·11	30·00	29·41
	Fe_2O_3	----	·10	----	----	----	·50	----	2·90
	FeO	1·14	·64	4·07	3·80	8·54	11·87	11·16	6·56
	MnO	----	----	----	----	----	·09	----	----
	MgO	14·89	14·09	9·90	9·47	8·60	4·45	7·94	8·00
	CaO	1·60	2·78	1·81	·98	1·33	·81	·65	1·65
	Na_2O	1·28	1·72	1·82	2·68	1·60	2·22	1·13	3·03
Corrected.	K_2O	·26	·16	·44	·21	·73	·24	·53	·16
Corrected.	H_2O	3·32	3·83	3·77	3·79	3·44	3·62	3·63	2·94
Corrected.	F	----	----	----	----	----	----	·55	----
		100·00	100·42	100·00	99·87	100·00	100·35	100·23	101·32
Original.	SiO_2	38·85		39·01		37·50		37·22	
Original.	H_2O	2·31		2·82		1·81		1·64	
Original.	Ign	3·19		3·32		2·49		2·39	

		Alabashka,			Brazil,	Pierrepont, N. Y.,		
		Black.			Green.	Black.		
		Rm. 20.	J. & C. 57.	Rm. 32.	Rgs. 41.	J. & C. 64.	Rm. 35.	Rgs. 50.
	TiO_2	---	----	----	----	----	----	·55
Corrected.	SiO_2	[35·44]	35·41	[35·90]	36·91	37·05	[34·98]	35·61
Corrected.	B_2O_3	[10·33]	10·14	[10·51]	9·87	9·09	[10·20]	10·15
	Al_2O_3	30·41	33·75	37·81	38·13	40·03	27·18	25·29
	Fe_2O_3	----	----	----	·31	----	----	·44
	FeO	15·59	13·42	5·83	3·19	2·36	9·08	8·19
	MnO	·54	----	1·13	2·22	2·35	----	----
	MgO	1·88	1·57	·92	·04	·32	10·13	11·07
	CaO	----	·17	----	·38	·47	2·91	3·31
	Na_2O	1·02	2·08	2·21	2·70	3·18	1·50	1·51
	K_2O	·47	·34	·42	·28	----	----	·20
Corrected.	Li_2O	----	----	1·30	1·61	·60	----	----
Corrected.	H_2O	3·88	3·41	3·57	3·64	3·23	4·02	3·34
Corrected.	F	·76	·28	·70	·14	1·15	----	·27
		100·32	100·57	100·30	99·42	99·83	100·00	99·93
Original.	SiO_2	36·19		38·06			36·64	
Original.	H_2O	1·11		2·23			3·01	
Original.	Ign	2·15		2·92			?	

With the present interpretation of Rammelsberg's analyses the ratios of SiO_2 : B_2O_3 have been assumed as 4 :1, while those of SiO_2 to the total equivalent of hydrogen atoms in the different analyses are as follows:

No. 1	No. 7	No. 11	No. 12	No. 20	No. 32	No. 35
4 : 20·7	4 : 19·8	4 : 20·5	4 : 20·06	4 : 19·6	4 : 19·9	4 : 20·2

*Compare the reference to this analysis on p. 115.

The agreement between the corrected analyses of Rammelsberg and those of the other investigators is very remarkable, and the ratios of SiO_2 to the total equivalent of hydrogen atoms approximate closely to 4:20 (the average is 4:20·1).

Seven complete analyses are also given by Rammelsberg and to them corrections for water have been applied, while the errors of the analysis have been distributed upon the SiO_2 and B_2O_3. The results are given below, together with Rammelsberg's figures for SiO_2, B_2O_3, H_2O and loss on ignition:

	No. of Analysis,	2	5	22	24	29	31	33
Corrected.	SiO_2 ...	[36·53]	[36·37]	[34·82]	[34·87]	[35·49]	[36·03]	[36·02]
	B_2O_3 ...	[10·66]	[10·61]	[10·16]	[10·17]	[10·35]	[10·51]	[10·51]
	Al_2O_3 ..	32·90	33·15	35·46	33·35	42·63	44·05	36·80
	FeO ...	·66	2·88	13·17	11·95	....	....	6·38
	MnO ...	....	....	·28	1·25	1·94	·92	·78
	MgO ...	11·79	10·89	1·52	·63	·39	·20	1·88
	CaO ...	1·25	·77	....	....	·45	....	....
	Na_2O ..	2·37	1·52	·98	1·75	2·60	2·00	2·47
	K_2O ...	·47	....	·09	·40	·68	1·30	·47
Corrected.	Li_2O ...	....	....	....	·84	1·17	1·22	·72
	H_2O ...	3·00	3·81	3·28	4·31	3·61	3·37	3·65
	F	·64	....	·41	·82	1·18	·70	·55
		100·27	100·00	100·17	100·34	100·49	100·30	100·23
Original.	SiO_2 ...	38·09	38·33	36·11	36·22	38·19	38·85	38·46
	B_2O_3 ...	11·15	9·86	11·64	10·65	9·97	9·52	9·73
	H_2O ...	2·05	2·81	1·26	2·21	2·00	2·41	2·31
	Ign	2·93	3·49	1·82	2·98	3·61	3·37	2·94

A comparison of the corrected analyses with the figures given by Rammelsberg indicate that B_2O_3 has been determined with a good degree of accuracy. His water is always low and his silica high. The ratios of SiO_2 to the total equivalent of hydrogen atoms in the corrected analyses are as follows:

	No. 2	No. 5	No. 22	No. 24	No. 29	No. 31	No. 33
Ratio	4:20·0	4:20·3	4:20·4	4:20·7	4:21·8	4:21·4	4:20·2

Two of the hydrogen ratios are very high; four of them approximate closely to 4:20·0; the average is 20·7.

The results obtained by applying similar corrections to the remaining twenty analyses are given in the table on page 113, together with Rammelsberg's figures for SiO_2, H_2O and loss on ignition. In the last column the ratios of the total equivalent of hydrogen atoms are given, one quarter of the corrected SiO_2 being taken as unity.

The ratios of the silica to the hydrogen atoms in these twenty analyses exhibit a rather wide variation, from 4:18·7 to 4:21·8. The average, however, is 4:20·4, and the average for all of his thirty-four analyses is also 4:20·4, or approximately 4:20.

No.	Locality.	Corrected. SiO₂	Corrected. B_2O_3	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Li_2O	Corrected. H_2O	F	Original. SiO_2	Original. H_2O	Original. Ign.	Ratio.
3	Eibenstock	[35·41]	[10·32]	30·86	4·36	....	11·62	0·88	2·27	0·30	....	3·98	....=100·00	37·75	2·82	3·50	20·8
4	Zillerthal	[36·39]	[10·62]	32·55	2·80	0·36	10·46	0·16	2·13	0·37	....	3·85	0·36=100·15	38·51	3·04	3·54	20·1
6	Texas, Pa.	[35·76]	[10·43]	34·56	2·98	0·09	9·11	0·71	2·00	0·73	....	3·63	....=100·00	38·45	2·80	3·30	20·6
8	Godhaab	[34·47]	[10·06]	34·26	4·42	....	9·51	1·25	2·00	0·43	....	3·60	....=100·00	37·70	2·61	3·11	21·8
9	Havredal	[34·88]	[10·18]	31·26	7·58	....	9·43	0·80	1·78	0·32	....	3·77	....=100·00	37·11	2·43	2·93	20·9
10	St. Gothard	[36·40]	[10·62]	31·41	7·23	....	7·27	1·31	1·43	0·28	....	4·05	....=100·00	38·00	2·75	3·25	19·5
13	Elba	[35·48]	[10·35]	30·02	9·93	0·58	6·77	0·72	2·19	0·25	....	3·60	0·15=100·06	38·20	2·29	2·50	19·6
14	Unity, N. H.	[33·57]	[9·79]	30·44	13·23	....	6·32	1·02	1·94	....	....	3·69	....=100·00	36·29	1·72	2·22	21·3
15	Krumman	[34·38]	[10·03]	34·12	11·58	....	3·84	0·44	1·36	0·30	....	3·95	....=100·00	36·43	2·11	2·66	21·2
16	DeKalb, N. Y.	[34·65]	[10·11]	31·86	12·55	0·51	3·49	....	2·04	0·30	....	4·31	0·31=100·13	37·07	2·48	2·92	20·7
17	Langenbeilau	[35·94]	[10·48]	31·63	11·64	....	3·65	0·62	1·93	0·82	....	3·29	....=100·00	37·24	1·45	2·00	18·9
18	Bovey Tracy	[36·01]	[10·50]	30·22	13·82	0·40	2·62	0·50	1·39	0·65	....	3·63	0·45=100·19	37·94	1·74	2·09	18·7
19	Krumbach	[33·96]	[9·90]	32·21	12·82	1·50	2·32	0·40	1·43	0·46	....	4·63	0·64=100·27	36·25	2·34	3·21	21·3
21	Andreasberg	[34·05]	[9·93]	30·34	17·40	0·11	0·78	0·72	1·36	0·58	....	4·24	0·85=100·36	36·06	1·54	2·31	20·5
23	Sarapulsk	[36·92]	[10·77]	31·53	10·30	2·68	1·06	....	2·37	0·33	....	3·58	0·80=100·34	38·30	1·81	2·44	18·8
25	Elba	[34·40]	[10·03]	34·15	10·52	1·87	1·68	....	2·30	0·75	0·32	3·71	0·47=100·20	37·14	1·90	2·54	20·8
26	Elba	[35·81]	[10·45]	33·19	5·43	3·59	4·30	0·30	2·04	0·38	....	3·94	0·98=100·41	38·24	2·00	3·34	20·1
27	Elba	[36·09]	[10·52]	41·89	1·38	2·51	0·41	....	2·40	0·34	0·74	3·43	0·50=100·21	37·74	2·60	3·28	20·9
28	Shaitansk	[35·64]	[10·40]	43·97	....	1·53	1·62	0·62	1·53	0·21	0·48	3·59	0·70=100·29	38·26	2·49	3·59	21·8
30	Rozena	[37·15]	[10·84]	41·83	....	0·95	0·61	....	1·37	2·17	0·41	3·98	1·19=100·50	41·16	2·57	3·98	20·3

As already stated, Rammelsberg admits that his water determinations are too low; he also states that the formula for a complex mineral like tourmaline cannot be determined from a few analyses but must be derived rather from the average of many determinations. If then it may be assumed that his loss on ignition, when corrected for the oxidation of the iron, gives a close approximation to the amount of water, his results on the whole agree with the formula $H_{20}B_2Si_4O_{21}$. It may also be stated that if the analyses are not corrected they lead to no satisfactory formula.

REVIEW OF RIGGS' ANALYSES.—Twenty analyses of American tourmalines were made by Riggs, and the ratios derived from them furnish the very best evidence of the accuracy of his results. The ratios are as follows:

No.	SiO_2	:	B_2O_3	:	Total hydrogen.	No.	SiO_2	:	B_2O_3	:	Total hydrogen.
36.	4	:	0·90	:	20·2	46.	4	:	0·96	:	20·2
37.	4	:	0·93	:	20·5	47.	4	:	0·98	:	20·08
38.	4	:	0·92	:	19·5	48.	4	:	1·01	:	20·06
39.	4	:	0·94	:	19·7	49.	4	:	1·01	:	20·12
40.	4	:	0·96	:	19·3	50.	4	:	0·98	:	19·2
41.	4	:	0·92	:	19·7	51.	4	:	0·91	:	19·6
42.	4	:	0·97	:	19·8	52.	4	:	0·94	:	20·11
43.	4	:	0·94	:	20·03	53.	4	:	0·97	:	18·9
44.	4	:	0·88	:	20·2	54.	4	:	0·98	:	19·8
45.	4	:	0·95	:	20·03	55.	4	:	1·01	:	20·6

The average of these ratios is 4 : 0·95 : 19·88, or a very close approximation to 4 : 1 : 20, which indicates that tourmaline is derived from the acid $H_{20}B_2Si_4O_{21}$. It is pointed out by Riggs that "the boric acid found invariably falls short of the theory." This is generally, though not always, the case, and it is presumed that this slight defect in the analyses is due to the fact that it is not always possible to obtain a correct determination of boric oxide by the Gooch method without a second fusion of the silicate with sodium carbonate, which Riggs does not mention having made. It is not indicated by the ratios that these analyses "give as a general tourmaline formula the simple boro-orthosilicate $R_9BO_2 2SiO_4$" suggested by Riggs. The nearest approach to this is analysis No. 53, in which the ratio of SiO_2 to the total hydrogen is 4 : 18·9. The ratios with few exceptions show a very close approximation to the rational numbers 4 : 1 : 20. In eleven cases the numbers for the hydrogen ratios vary between the narrow limits 19·8 and 20·2. How exact the analyses must be in order to yield such ratios may be best understood when it is known that a difference of one-half of one per cent in the estimation of either silica or water would change the numbers of the hydrogen ratio ± 0·27 in the one case and ± 0·38 in the other. If the silica were one-half of one per cent high and the water correspondingly low, the effect upon the ratio would be to change it from 4 : 1 : 20 to 4 : 0·99 : 19·35. The evidence is therefore convincing that, with the exception of analysis No. 53 (brown tourmaline from Gouverneur, N. Y.), the analyses of Riggs are very exact, and also that the material he analyzed was very pure.* Referring to page 111, it will be observed that analysis No. 53 is the one which compares most unfavorably with Rammelsberg's corrected analyses. If the silica in this analysis were 1·25 per cent lower and the Al_2O_3 correspondingly higher, the agreement with Rammelsberg's corrected analysis would be quite satisfactory, and the ratio would correspond with the theory. Leaving out of consideration this one analysis, which may be considered as either defective or made upon impure material, the average of the ratios of Riggs' analyses becomes 4 : 0·95 : 19·91.

The analyses of Riggs were very severely criticized by Rammelsberg, who characterized tourmaline analysis as "*Kein Thema für Anfänger*," but in the light of our present investigation we find the results very accurate, and it may justly be said that we are indebted to Riggs for the best series of tourmaline analyses that has ever been made. In fact, our conclusions regarding the composition of the mineral might readily have been deduced from his results alone.

REVIEW OF THE ANALYSES OF JANNASCH AND KALB.—Nine analyses were made, from which the following ratios have been calculated:

No.	SiO_2	:	B_2O_3	:	Total hydrogen.	No.	SiO_2	:	B_2O_3	:	Total hydrogen.
56.	4	:	0·96	:	19·7	61.	4	:	0·95	:	20·2
57.	4	:	0·99	:	19·8	62.	4	:	0·80	:	20·00
58.	4	:	0·95	:	20·4	63.	4	:	0·98	:	19·7
59.	4	:	0·92	:	18·8	64.	4	:	0·84	:	20·01
60.	4	:	0·88	:	20·4	Average,	4	:	0·92	:	19·9

These analyses, like those of Riggs, bear every evidence of having been made with great precision, and the ratios, with the single exception of No. 59, approximate closely to 4 : 1 : 20, thus furnishing additional evidence that the acid from which all tourmalines are derived is $H_{20}B_2Si_4O_{21}$. The analyses do not indicate the general formula $R_9 . BO_2 . 2SiO_4$, proposed by Jannasch and Kalb. Their boric oxide determinations are in all cases a trifle too low for the theory, but it is believed that the reason for this is to be sought in imperfections of the method[*] for determining this constituent in a complex silicate. The analyses are excellent, and they rank with those of Riggs, among the best analyses of tourmaline that have been made. From our own experience, however, it is very questionable whether tourmaline contains so much ferric iron as recorded in some of these analyses (2·90 to 6·68 per cent).

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* In a personal communication from Professor Riggs the following statement is made concerning the quality of the material investigated by him: "The material analyzed was of excellent quality, selected with great care. The colorless, pink and light green varieties were transparent, gem-like crystals, and the material of the rose-colored, brown and black varieties was, in my opinion, equally pure." Dated, Hartford, January 4th, 1899.

THE ANALYSES OF SCHARIZER.—The ratios of the three analyses are as follows:

No.	SiO_2	:	B_2O_3	:	Total hydrogen.
65............	4	:	0·70	:	20·9
66............	4	:	0·76	:	21·0
67............	4	:	0·74	:	20·2

By comparing these ratios with the ones which have been previously considered, it would seem that there are good grounds for believing that in these analyses the B_2O_3 determinations are too low, and that the bases have not been determined with extreme accuracy. The ratios of SiO_2 to the total hydrogen atoms in the main substantiate the formula $H_{20}B_2Si_4O_{21}$.

ANALYSES FROM MISCELLANEOUS SOURCES.—In looking over the literature a number of analyses have been found which need to be recorded. They have been made partly for the purpose of identifying the mineral and partly for the purpose of determining the character of the tourmaline from special localities, but none of them have been made for the special purpose of determining the chemical composition of the species. It seems sufficient to give the ratios only, which are as follows:

Locality.	Analyst.	SiO_2	:	B_2O_3	:	Total hydrogen.
69.[†]Mt. Bischoff..........	Sommerland.....	4	:	0·98	:	18·5
70. Campolongo..........	Engelmann......	4	:	0·82	:	17·4
71. Sysersk, Urals.......	Cossa and Arzruni	4	:	0·89	:	18·8
72. Montgomery Co., Md.	Chatard.........	4	:	0·84	:	20·4
73. Nevada Co., Cal......	Melville.........	4	:	...	:	20·8
74. Tamaya, Chili	Schwarz	4	:	1·02	:	19·1
75. Straschin, Bohemia...	Weisner	4	:	1·10	:	19·4
76. Urulza, Siberia	Stchusseff.......	4	:	0·85	:	19·0
77. Kolar, India..........	Chapman Jones..	4	:	0·87	:	19·1
	Average....	4	:	0·92	:	19·2

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[*] Bodewig, Zeitschr. für Kryst., viii, p. 211, 1883.

[†] 69, 70, 71 and 72 quoted in Dana's Mineralogy; 73, Bull. U. S. Geolog. Survey, No. 90, p. 39; 74, Zeitschr. deutsch. Geol. Gesell., xxxix, p. 238; 75, Min. u. Petr. Mitth., ix, p. 410; 76, Zeitschr. Kryst., xx, p. 93; 77, Min. Mag., xi, p. 61.

As indicated by the variations in the ratios, the analysts apparently have not had sufficient experience to enable them to deal successfully with such a difficult problem as the tourmaline analysis. The average of the ratios, however, approximates to 4 : 1 : 20 and thus substantiates our formula.

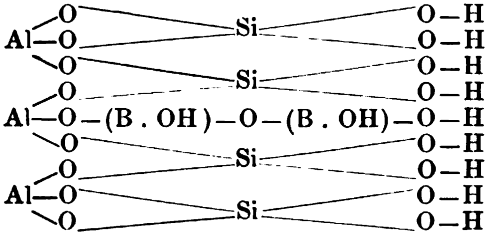
TITANIUM IN TOURMALINE.—Titanium seems to have been overlooked in the earlier analyses of tourmaline, but is reported in several of the analyses of Riggs, Jannasch and Kalb, and others. The quantity, however, has always been found to be small, amounting to over one per cent (reckoned as TiO_2) in only four of the analyses and to over 0·6 per cent in but two others. It has not been taken into consideration in making the foregoing calculations, partly because it would exert no appreciable influence on the final result, but chiefly because it is uncertain whether the titanium in this mineral plays the part of a tetravalent element replacing silicon, or of a trivalent element replacing aluminium. Although it may not be possible with the data now at hand to definitely settle this question, still the analyses furnish some evidence that the element should be regarded as trivalent. This result has been reached by considering titanium both as TiO_2 replacing SiO_2 and as Ti_2O_3 replacing Al_2O_3, and comparing the ratios derived from the four analyses in which the TiO_2 has been recorded as over one per cent. The results are as follows:

No.	Locality.	Premises.	SiO_2 :	B_2O_3	Total hydrogen.
51.	Monroe, Conn., Riggs	TiO_2, 1·61 per cent	4 :	0·88 :	18·9
		Neglecting titanium	4 :	0·91 :	19·6
		Ti_2O_3 1·45 per cent	4 :	0·91 :	19·97
53.	Gouverneur, N. Y., Riggs	TiO_2 1·19 per cent	4 :	0·95 :	18·5
		Neglecting titanium	4 :	0·97 :	18·9
		Ti_2O_3 1·07 per cent	4 :	0·97 :	19.2
56.	Snarum, Jannasch and Kalb	TiO_2 1·10 per cent	4 :	0·93 :	19·1
		Neglecting titanium	4 :	0·96 :	19·7
		Ti_2O_3 0·99 per cent	4 :	0·96 :	19·9
59.	Tamatawe, Jannasch and Kalb	TiO_2 1·22 per cent	4 :	0·90 :	18·4
		Neglecting titanium	4 :	0·92 :	18·8
		Ti_2O_3 1·10 per cent	4 :	0·92 :	19·1

In these four cases it will be observed that the calculations give the closest approximation to the normal tourmaline ratio when the titanium is regarded as Ti_2O_3. Moreover when the titanium is regarded as TiO_2 the departure from the normal ratio is so great that it does not seem probable that this is due wholly to defects in the analyses. Some very careful and exact analytical work must be done in order to decide this question definitely.

CONSTITUTION OF TOURMALINE.—The evidence is convincing that all tourmalines are derivatives of a complex borosilicic acid $H_{20}B_2Si_4O_{21}$, and it is believed that further analyses will not alter this result, although they may furnish important data concerning the constitution of the acid. All of the hydrogen atoms of this acid in tourmaline are not replaced by metals, for the different varieties have always been found to contain water, which indicates the presence of hydroxyl. The ratio of the silica to the hydrogen derived from water (hydroxyl) plus the fluorine is not constant, but varies in Riggs' and our analyses from 4 : 3·14 (pale green tourmaline from Auburn, Maine) to 4 : 2·48 (colorless tourmaline from De Kalb). In all of the analyses in which water has been estimated directly, a sufficient quantity has been obtained to yield two hydroxyls in the formula; in only a few cases has the amount been sufficient to yield three hydroxyls. We are thus led to believe in the existence of two hydroxyls in all tourmalines, and it seems natural to associate them with the two boron atoms. The acid consequently becomes $H_{18}(B.OH)_2Si_4O_{19}$. The small amount of fluorine which is found in many varieties of tourmaline presumably plays the same role as hydroxyl, or is isomorphous with it, as in the case of topaz, of chondrodite, and of other minerals containing fluorine and hydroxyl. The slight excess of hydrogen over and above the two hydroxyls may be regarded as basic hydrogen, which plays the role of a metal. Such a relation is not unknown in complex mineral compounds.*

One of the peculiar features of tourmaline is that varying proportions of metals of different valences and of essentially different character replace the hydrogens of the acid $H_{18}(B.OH)_2Si_4O_{19}$. In all cases thus far examined aluminium predominates and is present in sufficient quantity to replace more than half the hydrogens. From this it has been inferred that an aluminium-borosilicic acid $H_9Al_3(B.OH)_2Si_4O_{19}$ *is characteristic for all varieties of tourmaline.* The constitution of this acid may be expressed graphically as follows:



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* This Journal, xl, p. 396, 1890.

It would seem that the mass effect of the complex radical $[Al_3(B.OH)_2Si_4O_{19}]$, which has a valence of nine, is sufficiently pronounced to control or dominate all types of tourmaline. Thus it apparently makes no difference whether the nine hydrogens are replaced largely by aluminium and to a slight extent by alkalies; or largely by magnesium and to a slight extent by aluminium and alkalies; or to about an equal extent by aluminium, iron or magnesium and alkalies; the result in all cases is the mineral tourmaline, with its characteristic crystallization and its peculiar optical and electrical properties.

The following example (compare the ratio derived from the analysis of the green tourmaline from Haddam Neck, page 107) will illustrate the method of determining to what extent the nine hydrogens of the tourmaline acid, $H_9Al_3(B.OH)_2Si_4O_{19}$, are replaced by metals of different valences:

Ratio:		Total hydrogen equivalent, or 20 H.	2(OH, F).	18 H.	3 Al.	9 H.	
Al_2O_3		2·327		2·327	1·385	·942	÷ ·154 = 6·1 R‴
FeO	·059	·169		·169		·169	÷ ·154 = 1·1 R″
MnO	·056						
MgO	·008						
CaO	·046						
Na_2O	·068	·178		·178		·178	÷ ·154 = 1·2 R′
Li_2O	·110						
H_2O	·344	·404	·308	·096		·096	÷ ·154 = 0·6 H.
F	·060						
		20)3·078		2)2·770		9)1·385	9·0
		·154		1·385		·154	

From the ratio of the total hydrogen equivalent, $\frac{2}{20}$ (representing two hydroxyls) are deducted. The remainder, 18 H, is divided by two, thus determining the ratio of the nine H's replaced by Al_3 in the formula. The excess of the aluminium or trivalent metal ratio, R‴, together with the ratios of the bivalent metals, R″, the alkali metals R′ and the excess of hydrogen, H, represent nine H's, which are divided among the different constituents. Thus in the green tourmaline from Haddam Neck 6·1 hydrogens are replaced by Al (R‴), 1·1 by R″, 1·2 by R′ and there remains 0·6 excess of basic hydrogen.

The analyses of Riggs, Jannasch and Kalb, Scharizer and Chatard, given on page 555 of Dana's Mineralogy, together with our own analyses, practically include all varieties of tourmaline which have thus far been investigated, and in the following table are given the results of applying the foregoing method of calculation to them:

	No.	Locality.	Color.	Analyst.	R'''	R''	R'	H
Lithia Tourmalines.	1	Minas Geraes, Brazil	Pale-pink	Riggs, 37	6·7	0·3	1·2	0·8
	2	Rumford, Me.	Rose	Riggs, 36	6·5	0·2	1·2	1·1
	3	Brazil	Green	Jann. & Kalb, 64	6·3	1·1	0·9	0·7
	4	Auburn, Me.	Colorless	Riggs, 38	6·2	0·6	1·1	1·1
	5	Minas Geraes, Brazil	Pale-green	Riggs, 39	6·2	0·8	1·3	0·7
	6	Schüttenhofen, Bohemia	Red	Scharizer, 67	6·1	0·3	1·3	1·3
	7	Haddam Neck, Conn.	Pale-green	Authors	6·1	1·1	1·2	0·6
	8	Barra do Perahy, Brazil	Green	Jann. & Kalb, 63	6·0	1·1	1·4	0·5
	9	Rumford, Me.	Dark-green	Riggs, 42	6·0	1·3	1·1	0·6
	10	Minas Geraes, Brazil	Olive-green	Riggs, 41	5·9	1·1	1·3	0·7
	11	Auburn, Me.	Light-green	Riggs, 40	5·7	0·9	1·2	1·2
	12	Schüttenhofen, Bohemia	Blue-green	Scharizer, 66	5·5	1·2	1·2	1·1
	13	Auburn, Me.	Dark-green	Riggs, 43	5·3	1·5	1·1	1·1
Iron Tourmalines, No. 21 excepted.	14	Buckworth, Australia	Black	Jann. & Kalb, 62	4·7	2·9	0·7	0·7
	15	Paris, Me.	Black	Riggs, 44	4·7	3·0	0·5	0·8
	16	Auburn, Me	Black	Riggs, 45	4·7	3·1	0·5	0·7
	17	Alabashka, Russia	Black	Jann & Kalb, 57	4·7	3·2	0·5	0·6
	18	Mursinka, Russia	Black	Jann. & Kalb, 60	4·7	3·2	0·7	0·4
	19	Schüttenhofen, Bohemia	Blue-black	Scharizer, 65	4·5	3·0	0·5	1·0
	20	Piedra Blanca	Black	Jann. & Kalb, 58	4·4	3·2	0·6	0·8
	21	Montgomery Co., Md.	Green (*Cr*)	Chatard, 72	4·4	3·4	0·5	0·7
	22	Minas Geraes, Brazil	Black	Riggs, 46	4·3	3·5	0·5	0·7
Magnesia-Iron Tourmalines.	23	Stony Point, N. C.	Black	Riggs, 48	4·2	3·6	0·5	0·7
	24	Oláhpian	Black	Jann. & Kalb, 61	4·0	4·1	0·5	0·4
	25	Tamatawe	Black	Jann. & Kalb, 59	3·8	4·6	0·5	0·1
	26	Haddam, Conn.	Black	Riggs, 47	3·7	4·0	0·5	0·8
	27	Snarum, Norway	Black	Jann. & Kalb, 56	3·7	4·4	0·7	0·2
	28	Orford, N. H.	Dark-br'wn	Riggs, 52	3·6	4·1	0·6	0·7
	29	Monroe, Conn.	Dark-br'wn	Riggs, 51	3·4	4·1	0·7	0·8
	30	Nantic Gulf, Baffin's Ld.	Black	Riggs, 49	3·1	4·7	0·5	0·7
Magnesia Tourmal.	31	DeKalb, N. Y.	Colorless	Authors	2·5	5·7	0·3	0·5
	32	DeKalb, N. Y.	Colorless	Riggs, 54	2·2	5·7	0·4	0·7
	33	Gouverneur, N. Y.	Brown	Riggs, 53	2·2	5·6	0·4	0·8
	34	Hamburg, N. J.	Brown	Riggs, 55	2·0	6·2	0·2	0·6
Mg & Fe.	35	Pierrepont, N. Y.	Black	Riggs, 50	1·6	6·3	0·4	0·7

It will be observed that the extent to which the nine hydrogens of the acid $H_9Al_3(B.OH)_2Si_4O_{19}$ are replaced by metals, is very variable. The trivalent metal, R''', is chiefly aluminium, and the extent to which the hydrogens are replaced by it ranges from 6·7 to 1·6. The bivalent metals represented by R'' are chiefly iron and magnesium, and the extent to which the hydrogens are replaced by them ranges from 0·2 to 6·3. In general R'' and R''' are reciprocal. There is always some hydrogen replaced by the alkali metals R', and some basic hydrogen. The results are arranged in the table according to a decrease in the replacement of the hydrogens by R''', and according to this arrangement the different varieties of tourmaline fall into natural groups.

The first 13 examples are characterized by containing an appreciable quantity of lithium, while in the others none, or not more than traces of this element have been found; these may therefore be designated as *Lithia Tourmalines*, which form a natural group. In this group R′ is higher than in other varieties, while H is somewhat higher than the general average; R‴ is very high and R″ correspondingly low. This variety of tourmaline has its particular mode of occurrence, being found in pegmatite veins associated with quartz, albite, microcline, orthoclase, muscovite and lepidolite. The material is generally delicately colored and often transparent and of gem-like quality. It is difficultly fusible when heated before the blowpipe, fusibility=5–5½.

At the opposite extreme, 31–34, are varieties which may be designated as *Magnesia Tourmalines.* In these R″, which is chiefly magnesium, is very high and R‴ correspondingly low, while R′ reaches its lowest limit, 0·2 to 0·4. These varieties are light-colored and at times of gem-like quality. They are easily fusible before the blowpipe, fusibility=3. With these No. 35 should be associated, for it differs only in containing considerable iron which is isomorphous with the magnesium, hence the color of this tourmaline is black. The last five are alike in their mode of occurrence. They have probably been formed in limestones containing magnesium by the contact action of intruded igneous masses during the pneumatolitic period, when such masses were giving off heated aqueous vapors containing boracic acid and fluorine compounds. They are found in coarse crystalline limestone, associated with graphite, phlogopite, pyroxene, amphibole, scapolite and apatite. Contact metamorphisms of this nature have recently been described by Lacroix.*

The intermediate varieties (Nos. 14 to 30) with the exception of No. 21 are black or dark brown, owing to the presence of iron. These are the ordinary tourmalines found in granites, gneisses and schists, and sometimes in pegmatite veins intimately associated with lithia tourmaline, as at Auburn and Paris, Maine. They too have probably resulted from the mineralizing action of heated aqueous vapors containing boracic acid and fluorine compounds, given off during the pneumatolitic period of cooling igneous rocks. A contact metamorphism of this character, attended by the formation of tourmaline vein stone, has been very carefully described by Hawes.†

Nos. 14 to 22 (No. 21 excepted) are characterized by containing iron and only a little magnesia, hence they may be designated as *Iron Tourmalines;* Nos. 23 to 30 contain both magnesia and iron, and are hence designated as *Magnesia-Iron Tourmalines.* These two groups, however, grade into one another. The fusibility of these intermediate groups of tourmalines varies from 4·5 to 3, and decreases as the amount of iron and magnesia increase.

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* Le Granites des Pyrénées et ses Phenomènes de Contact, Bull. Carte Géologique de France, No. 64, Tome x, p. 54, 1898.

† The Albany Granite, New Hampshire, and its Contact Phenomena, this Journal, xxi, p 21, 1881.

Although in this series of thirty-five analyses there are pronounced groups or types of tourmaline which may be recognized, nowhere in the series do the ratios of R‴, R″, R′ and H approximate so closely to rational numbers that a definite formula for any one type can be instituted. Riggs and Jannish and Kalb, however, have given special formulas for different types of tourmaline (pages 100 and 101) based upon multiples of the acid $H_{18}(B.OH)_2Si_4O_{19}$. Deducting from their formulas appropriate multiples of the aluminium-boro-silicic radical $[Al_3(B.OH)_2Si_4O_{19}]$, it is found that the nine variable hydrogens of the tourmaline acid are replaced by metals of different valences in the following proportions:

		R‴	R″	R′	H
I. Lithia tourmaline	Riggs	7·0	0·0	1·3	0·7
	Jann. and Kalb	6·0	1·4	1·3	0·3
II. Iron tourmaline	Riggs	5·0	2·6	0·7	0·7
	Jann. and Kalb	5·0	3·0	0·7	0·3
III. Iron-magnesia tour.	Jann. and Kalb	4·0	4·0	0·7	0·3

Concerning the formulas for lithia tourmaline, Riggs' corresponds closely to No. 1, and Jannasch and Kalb's to Nos. 7, 8, 9 and 10 of our series (compare the table on p. 120), but neither of these complicated formulas furnishes a satisfactory expression for this type as a whole. Similar statements might be made concerning their formulas for iron tourmalines and for iron-magnesia tourmalines. The endeavor to express the composition of tourmaline or of one of its types by a definite formula may be compared to the attempt to express the composition of the dark varieties of sphalerite by a formula. Thus $Zn_{11}Fe_4S_{15}$ would correspond to sphalerite, containing about 50·5 per cent of zinc and 15·7 per cent of iron, but zinc and iron are isomorphous and can mutually replace one another in sphalerite, and a variety containing less iron would have to be expressed by a different formula. When, however, we understand the isomorphous relations existing between zinc and iron, and express the composition by RS, where R=Zn and Fe, the composition becomes very much simplified.

In tourmaline we have an isomorphous relation of a very peculiar nature, for in the acid $H_9Al_3(B.OH)_2Si_4O_{19}$ the nine hydrogens may be replaced to a large extent either by the trivalent metal aluminium or by the bivalent metals magnesium and iron without any decided change in crystalline form. This leads to the consideration of a certain phase of isomorphism which, as it seems to us, has not been considered with sufficient care, namely, the mass effect of complex radicals in influencing or controlling crystallization. Thus in their simple salts we do not regard sodium and potassium as isomorphous with calcium, but in some complex silicates, zeolites for example, we recognize Na_2 and K_2 as isomorphous with, or at least capable of replacing, calcium, barium and strontium. In some of the phosphates, dickinsonite and fillowite for example, we have sodium (Na_2) playing the same role as calcium, manganese and iron in replacing the hydrogens of phosphoric acid. In the garnet-sodalite group we have minerals with isometric crystallization, to which the following formulas have been assigned:*

$$\begin{array}{rl} \left.\begin{array}{rl} Ca_3Al_2(SiO_4)_3 & \text{Grossularite} \\ Fe_3Al_2(SiO_4)_3 & \text{Almandite} \end{array}\right\} & \text{Garnet} \\ (Cl-Al)Na_4Al_2(SiO_4)_3 & \text{Sodalite} \\ (NaSO_4-Al)Na_4Al_2(SiO_4)_3 & \text{Noselite} \\ (NaSO_4-Al)(Na_2, Ca)_2Al_2(SiO_4)_3 & \text{Haüynite} \\ (NaS_3-Al)Na_4Al_2(SiO_4)_3 & \text{Lazurite} \\ [(OH, F, Cl)_2.Al]_6Al_2(SiO_4)_3 & \text{Zunyite} \end{array}$$

When it is taken into consideration that isometric crystallization is exceptional in the group of silicates, we are led to believe that the sexivalent radical $[Al_2(SiO_4)_3]$, by virtue of its mass effect, controls or dominates the crystallization of these minerals. Not only are they isometric, but, with the exception of zunyite, which is tetrahedral, they all crystallize commonly in dodecahedrons. In sodalite, noselite and lazurite, such unlike constituents as chlorine, and the univalent sulphate and polysulphide radicals $(NaSO_4)'$ and $(NaS_3)'$ play the same part in the complex molecules. It is moreover probable that these unlike constituents are isomorphous in the sense that they can mutually replace one another, for Brögger and Bäckström have described homogeneous material containing the lazurite, haüynite and sodalite molecules, while appreciable quantities of chlorine are almost always found in noselite and haüynite, thus indicating the presence of the isomorphous sodalite molecule. It is to be expected that the larger and more complex the radical the more potent will be its mass effect in controlling or determining the crystal form. Thus in sodalite, noselite and haüynite the radical is very large, $[R'_4Al_2(SiO_4)_3]$, $R'_4=Na_4$ or Ca_2.

Tourmaline, it would seem, furnishes an example somewhat analogous to that presented by the garnet-sodalite group. In this acid $H_9Al_3(B.OH)_2Si_4O_{19}$ the mass effect of the complex radical $[Al_3(B.OH)_2Si_4O_{19}]$ is so great, or, the role played by the replacement of the nine hydrogens is so subordinate, that the bivalent elements, Fe, Mg, Mn and Ca, and to a slight extent the alkalies, Li, Na and K, can replace aluminium as isomorphous constituents. This conclusion in some respects is analogous to that reached by Rammelsberg, who stated in 1870 that all tourmalines were derived from an acid H_6SiO_5, in which the six hydrogens were replaced in varying proportions by R'_6, R''_3, Al_2 and B_2. Applying Rammelsberg's idea to the acid $H_{18}(B.OH)_2Si_4O_{19}$, all varieties of tourmalines may be regarded as mixtures of the molecules

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* Brögger and Bäckström, Zeitschr. für Kryst., xviii, p. 209, 1890.

$R'_{18}(B.OH)_2Si_4O_{19}$, $R' =$Li, Na, K and H
$R''_9(B.OH)_2Si_4O_{19}$, $R'' =$Fe, Mg, Mn and Ca
$R'''_6(B.OH)_2Si_4O_{19}$, $R'''=$Al, Cr and small amounts of Fe and Ti.

It seems more logical and satisfactory, however, to consider all varieties of tourmalines as salts of the acid $H_9Al_3(B.OH)_2Si_4O_{19}$, in which the complex aluminium-borosilicic acid radical $[Al_3(B.OH)_2Si_4O_{19}]$ exerts a *mass effect* by virtue of which the remaining hydrogens may be replaced by metals of essentially different character without bringing about any pronounced change in crystalline form.

Note concerning the detection of ferrous and ferric iron in Silicates; by S. L. Penfield and H. W. Foote.

In the preliminary work connected with the study of the methods of the tourmaline analysis, considerable time was devoted to ferrous and ferric iron determinations. The ordinary method of dissolving in a mixture of hydrofluoric and sulphuric acids and titrating with potassium permanganate can not be applied readily to tourmaline because it is extremely difficult to dissolve the mineral. Riggs overcame this difficulty by using very fine powder and heating under pressure in a heavy platinum crucible provided with a lid which was held down by clamps. Jannasch and Kalb succeeded in decomposing the exceedingly fine, elutriated powder by heating in sealed glass tubes with a mixture of sulphuric and hydrofluoric acids, but the method was far from satisfactory. We have employed fusion with borax. In order to test the method, silicates containing varying proportions of ferrous and ferric iron were first carefully standardized by the method described by Pratt.* The powdered silicate and borax glass were then fused in a platinum boat in a combustion tube, through which a current of either nitrogen or carbon dioxide gas was conducted. These gases were first freed from all traces of oxygen by conducting them over a roll of heated bright copper gauze at one end of the tube. Decomposition is thus readily effected without any appreciable oxidation. After fusion the material can be dissolved in dilute sulphuric acid and titrated with potassium permanganate. With small quantities of iron the method gives very satisfactory results, but ferric iron suffers a slight reduction during fusion, hence the method can not be recommended as a quantitative one when accuracy is required. The amount of reduction is nearly proportional to the amount of ferric iron, and when about 6 per cent of Fe_2O_3 is present the error amounted to about 0·3 per cent. It is certain, however, that very satisfactory determinations of ferrous and ferric iron might be obtained by means of this method, by applying a correction which could be determined by experimenting with some artificial mixture of silicates containing approximately the same amount of ferric oxide as the mineral. It is difficult to understand the cause of this reduction, which was first noted by Rammelsberg,* and afterwards carefully studied by Suida.†

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* This Journal, xlviii, p. 149, 1894.

Fusion with borax furnishes, however, a most excellent means for decomposing insoluble silicates, when qualitative tests for ferrous and ferric iron are desired. The application of the method is as follows: The mineral and some borax glass are heated in a closed-tube over a Bunsen-burner flame until decomposition is complete, or nearly so. Water is then dropped upon the hot glass in order to crack it, and, when cold, the end of the tube is broken up and transferred to a test-tube. About 3^{cc} of dilute hydrochloric acid are then added, and the acid is boiled vigorously until the material is dissolved, when about 5^{cc} of cold water are added. The liquid, after being divided into two portions, may then be tested with potassium ferricyanide for ferrous iron, and with either ammonium thiocyanate or potassium ferrocyanide for ferric iron. The results are very satisfactory and decisive, and although there is a tendency for ferric iron to undergo slight reduction during fusion, and also a tendency for ferrous iron to undergo slight oxidation during the manipulation, these defects are so trifling that practically they may be disregarded.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School, January, 1899.

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* Zeitschr. der deutsch. geolog. Gesell., xxiv, p. 69, 1872.
† Min. Mittheilung, Tschermak, 1876, p. 175.

ART. XIII.—*Littoral Mollusks from Cape Fairweather, Patagonia;* by HENRY A. PILSBRY. (With Plate I.)

IN the course of his paleontological explorations in Patagonia in the interest of Princeton University, Mr. J. B. Hatcher found time to make a small gathering of marine shells, at the locality named above. The scarcity of information upon the fauna of the east coast of South America makes it desirable to place the facts gained from even small collections on record, to the end that the limits of the faunal provinces of this coast may be more exactly defined, and their characteristics more fully exposed.

The fauna at the point in question is typically Magellanic, with but little admixture of types from the Argentine fauna of La Plata region. *Nacella*, *Photinula* and *Trophon*, *Plaxiphora* and littoral *Brachiopoda*, all occurring in a gathering so small as this, at once indicate the western and not northern origin of this mollusk population. *Bullia* alone is more northern in distribution, this being its most southern outpost.

The addition of the genus *Sphenia* to the Magellanic fauna is interesting and unexpected.

The figures on Plate I are three-fourths natural size.

MURICIDÆ.

Trophon Gerversianus Pallus.
Trophon Gerversianus Phillipianus Dkr.
Trophon fasciculatus Hombron and Jacquinot.
Trophon textiliosus Hombr. and Jacq. Pl. I, fig. 4.

Shell fusiform, white or slightly buff tinted, with moderately dilated body-whorl and short oblique or subvertical anterior channel. Whorls about 6, convex, separated by a deep suture, the last dilated toward the lip. Sculpture of numerous subregular rounded spiral cords (28–34 on body-whorl, 8–11 on penultimate whorl), separated by much narrower linear grooves, and numerous vertical folds, which are rather closely placed, separated by intervals narrower than themselves, are somewhat arcuate in harmony with the lines of growth and become obsolete upon the base. There are about 20 (18–21) folds upon the penultimate whorl, pretty regular and equal; but upon the latter part of the last whorl they become irregular or in part obsolete. Aperture ample, over half the total length of the shell, the outer lip somewhat expanding and faintly crenulated; columellar lip with a smooth white callous, reflexed over and closing the axial chink; siphonal fasciole well developed.

Alt.	diam.	alt. of aperture
36	23 mm.	22 mm.
39	21	21

The original description and figures were from a young shell. The species has not hitherto been recognized, probably owing to this circumstance. Mature specimens collected by Mr. Hatcher are here described and illustrated. The figures referred to *decolor* Phil. in the Voyage au Pol Sud. (Zool., pl. 25, f. 6–8), look like adults of *textiliosus.*

T. textiliosus has been reckoned a synonym of *T. Gerversianus* by Tryon (Man. Conch. II and III), but this is only another example of the "lumping" practised by him in dealing with *Trophon.*

It differs conspicuously from most other Cape Horn Trophons in its less rude sculpture and symmetrical contours. *T. decolor* Phil. has a much shorter anterior canal, purple interior and fewer spirals. In *T. cancellinus* Ph. the lip is thickened and dentate within. *T. crispus* Gld. differs in sculpture; and *T. liratus* Couth., which is apparently the most nearly allied species, has the anterior canal longer, and there are fewer spiral grooves. Specimens are in the collection of the Academy of Natural Sciences of Philadelphia from "Santa Cruz River, Patagonia, Wm. Bell."

BUCCINIDÆ.

Euthria plumbea Phil.

Enthria sp. undet. Like *plumbea,* but finely spirally striated throughout. All of the specimens are beach-worn and not suitable for description.

Bullia globulosa Kiener.

VOLUTIDÆ.

Scaphella Ferussaci Don.
Scaphella ancilla Sol.

CALYPÆTRIDÆ.

Trochita corrugata Reeve. Varies toward forms in which the radial ribs almost disappear.

TROCHIDÆ.

Photinula cœrulescens King.
Photinula tœniata Wood.

Photinula pruinosa Mab. and Roch. Quite distinct from the longer-known species in its Gibbula-like contour and wide, flattened, lusterless columella.

PATELLIDÆ.

Nacella œnea magellanica Gmel.
Nacella œnea deaurata Gmel.

MOPALIIDÆ.

Plaxiphora setigera King.

PECTENIDÆ.

Pecten patagonicus King.

MYIDÆ.

Sphenia Hatcheri n. sp. Pl. I, figs. 5, 6.

Shell cretaceous and dull, stout, rather strong, moderately inflated, with broad, somewhat truncated, closed anterior, and narrow, abruptly truncate and widely gaping posterior end. Beaks small, in close contact and eroded at the tips, nearly median, being one mm. nearer the posterior than the anterior end; projecting somewhat above. Dorsal margin highest anterior to the beaks, thence sloping downward and posteriorly; anterior end widely subtruncate, arcuate; ventral margin slightly arcuate. Sculpture, fine, nearly regular concentric grooves separating wider intervals on the anterior portion of shell, disappearing posteriorly, where there are only some rude, irregular wrinkles at unequal intervals. Face of the chondrophore in right valve directed ventrally; that of the left valve partially erect. Interior white or stained, porcellanous, the adductor scars distinct, pallial line and very broad posterior sinus indistinct. Length 17, altitude 9·5, diam. 7·2^{mm}. A single specimen collected. The genus has not before been reported from this region to my knowledge.

MACTRIDÆ.

Mactra (*Mactra* s. str.) *Jousseaumi* Mabille and Rochebrune. Pl. I, figs. 1, 2, 3.

The specimen figured, one of several collected, agrees with Mabille and Rochebrune's short and unsatisfactory description* as far as that goes, except in size; their specimen measuring, length 45, alt. 34, diam. 18^{mm}. The proportions however are similar, the figured specimen measuring 67, 48, 28^{mm}. The subtriangular form, perfectly straight slope of the valve margins in front of the beaks, and obtuse siphonal extremity, as well as the details of hinge structure, are sufficiently shown in the figure. In external texture it is like an old *Spisula solidissima*, but the thin, light yellowish-olive cuticle adheres in small ragged patches.

MYTILIDÆ.

Mytilus magellanicus Gmel.
Mytilus sp. A single small specimen.
Mytilus edulis L.

TEREBRATELLIDÆ.

Terebratella dorsata Gmel.

Academy of Natural Sciences, Philadelphia.

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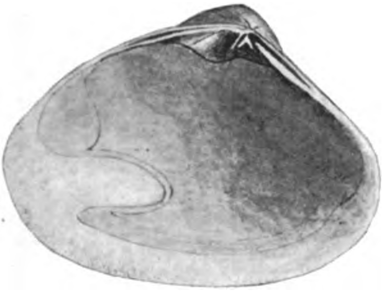
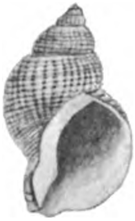
* Miss. Sci. du Cap Horn, Mollusques, p. 106.

1.

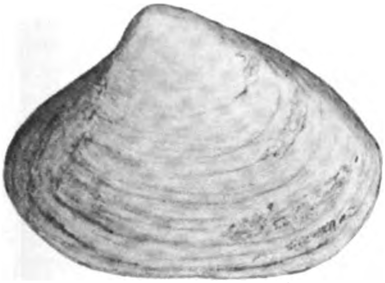


2.

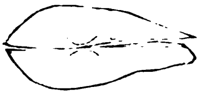
4.



3.



5.



6.

Littoral Mollusks from Cape Fairweather, Patagonia.

ART. XIV.—*The Thermodynamic Relations for Steam;* by G. P. STARKWEATHER.

AMONG the various thermodynamic relations for a gas that between pressure, volume and temperature, the 'equation of condition' is one of the most important. To apply to the case of steam such equations, either empirical, or based on assumptions hardly justifiable, have been formed by Zeuner,[*] Schmidt,[†] Ritter,[‡] and Antoine.[§] Of these Zeuner's and Schmidt's satisfied the saturation line well, but they, as well as Antoine's, had the fatal defect that the constant which determines the limiting value of $\frac{pv}{T}$ for very great volumes was assumed incorrectly.

Van der Waals' celebrated pamphlet in 1873 gave a rational form to the equation of condition, and Clausius' generalization [||] of the same,

$$p=\frac{RT}{v-a}-\frac{f(T)}{(v+\beta)^2},$$

has been for the most part adopted for various substances. Equations based upon this generally have the aim of satisfying not only the gaseous state but also the liquid. A relation between a and β, and also the value of $f(T)$ at the critical point, follow from the fact that at that point not only does this equation hold, but also its first and second partial derivatives with respect to v. R is fixed by the chemical composition of the substance, while $f(T)$ is so determined as to satisfy the corresponding saturation pressures and temperatures by Clausius' method.[¶] The value of a (hence β, from the relation mentioned above) is so chosen as to satisfy the water line at some point.

The best application of this method to steam has been given by Van Laar,[**] who has taken for $f(T)$ the form adopted by Sarrau[††] for carbonic acid, $\kappa\gamma^{-T}$, κ and γ being constants. On applying Clausius' method of determining the corresponding saturation pressures and temperatures to the equation he has found a good agreement.

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[*] Zeitschr. des Ver. Deutsch. Ingen., xi, p. 42, 1867.

[†] Zeitschr. des Ver. Deutsch. Ingen., xi, pp. 649, 771, 1867, and Prag Abhandl., i, 1868.

[‡] Wied. Ann., iii, p. 447, 1878.

[§] Comptes Rendus, cx. p. 632, 1890.

[||] Wied. Ann, xiv, pp. 279, 692, 1881.

[¶] Wied. Ann., xiv, p. 692, 1881.

[**] Zeitschr. für Phys. Chem., xi, p. 433, 1893.

[††] Comptes Rendus, ci, pp. 941, 994, 1145, 1885.

But Van Laar's equation does not satisfy the saturation volumes. The writer has shown in a previous paper* that the saturation volumes as calculated from Regnault's latent heats are entirely out of accord with those directly measured by Battelli,† and has given reasons for preferring the former. From these Van Laar's equation deviates 2·5 per cent. Even should we assume Battelli's experiments to be correct instead of Regnault's the deviations would still exceed 1 per cent.

Were it certain that the equation were necessarily of Clausius' form, holding for the liquid as well as the vapor, the method would be exact, and we should simply have to say so much the worse for the experiments. But all we know concerning the last term of the second member is that at large volumes at any given temperature it must be sensibly $\frac{c}{v^2}$, as has been shown by Van der Waals. If we replace $\frac{1}{(v+\beta)^2}$ by some other function of v which is sensibly $\frac{1}{v^2}$ at large volumes, the application of Clausius' method becomes very complicated, if not, indeed, impossible. The failure of Van Laar's equation to satisfy the facts would seem to show that the form $\frac{f(\mathrm{T})}{(v+\beta)^2}$ is not sufficiently correct for the water line, at least.

Abandoning the attempt to satisfy the water line throughout, we might still consider $\frac{f(\mathrm{T})}{(v+\beta)^2}$ as sufficiently accurate for it in the vincinity of the critical point, the relations for that point still holding true. The equation would thus apply to steam for all states. In this case, if we give the equation Clausius' general form, his method for determining $f(\mathrm{T})$ does not apply, and we are free to choose it so as to satisfy the saturation volumes. This has apparently never been done. The writer has attempted it, but without success. $f(\mathrm{T})$ would necessarily decrease very rapidly with increasing temperature. Thus at 100° C., 200° C. and 365° C. (the critical temparature) $f(\mathrm{T})$ would have the respective values 59·5, 21·5 and 13·5. Moreover, the great fall from 100° to 200° is out of accord with the change from 200° to 365°. This seems to indicate that the type of formula selected will not satisfy the facts.

There remains the following problem, to obtain equations which shall satisfy the experiments within ordinary limits. Such equations would suffice for most purposes, and moreover the writer hopes to draw from them some theoretical conclusions of interest. A p-v-T equation should be of the form

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* This Journal, Jan. 1899, p. 13.

† Mem. R. Acc. Sc. di Torino (ii), 43, 1893.

$$p=\frac{\mathrm{RT}}{v-a}-f(\mathrm{T})\phi(v).$$

In this R must have its theoretical value deduced from the chemical composition of water, while a, on account of the extreme incompressibility of water, should have a value not much less than 0·001, v being in cubic meters per kilogram. Moreover, $\phi(v)$ must be sensibly $\frac{c}{v^2}$ for large values of v.

The writer has formed the following equation, to hold for volumes not much less than 0·12 cubic meters per kilogram. At such volumes it should not be used when the pressure much exceeds 11700$^{\mathrm{mm}}$, although for larger volumes it may be applied to higher pressures.

$$p=\frac{\mathrm{RT}}{v-a}-\frac{\mathrm{A}}{\mathrm{T}v^{\frac{3}{2}}(v^{\frac{1}{2}}+\gamma)}.$$

If p is expressed in millimeters and v in cubic meters per kilogram the constants are

$\log \mathrm{R} = 0{\cdot}539990$ $\qquad a = 0{\cdot}0008$
$\log \mathrm{A} = 4{\cdot}632127$ $\qquad \gamma = 1{\cdot}20484$

The value of R is that given by Van Laar,* modified by the fact that he places the absolute zero at $-273^\circ{\cdot}2$ instead of $-273^\circ{\cdot}7$, as assumed here.

How well the equation agrees with the saturation line is shown by the following table. In the first column is given the temperature absolute, in the second the pressure, p_C, calculated from the formula by means of the saturation volumes, in the third the pressure according to Regnault, p_R, and in the fourth the fractional deviation, d, of p_C from p_R.

T	p_C	p_R	d	T	p_C	p^R	d
313·7	55·11	54·91	+·0036	403·7	2026·4	2030·3	—·0019
323·7	92·37	91·98	+·0042	413·7	2712·2	2717·6	—·0020
333·7	149·34	148·79	+·0037	423·7	3573·3	3581·2	—·0022
343·7	233·66	233·08	+·0025	433·7	4641·7	4651·6	—·0021
353·7	355·04	354·62	+·0012	443·7	5950·9	5961·7	—·0018
363·7	525·64	525·39	+·0005	453·7	7538·1	7546·4	—·0011
373·7	760·01	760·00	0	463·7	9442·7	9442·7	0
383·7	1074·6	1075·4	—·0008	473·7	11700	11689	+·0009
393·7	1489·5	1491·3	—·0012				

With the exception of those near 323°·7 the variations are insignificant, but the change in sign at 463°·7 shows that the equation will not hold for much smaller volumes. The larger deviations near 323°·7 are not due to the form chosen for the equation, for at such large volumes the gas deviates only slightly from the law of Boyle and Charles. A sufficient explanation for these deviations lies in the values of p and $\frac{dp}{dt}$, Regnault's formula for which is incorrect at low pressures, due to the fact that he did not recognize the sudden change in $\frac{dp}{dt}$ at 0°. This matter will be considered later.

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* Zeitschr. für Phys. Chem., xi, p. 433, 1893.

p and T being given, the formula is not convenient for obtaining v, but if an approximate value of v be found from Boyle and Charles' law, p obtained, and then v corrected by the assumption

$$\delta \log p = -\delta \log v,$$

a second correction will generally be sufficient.

If the factor $\frac{1}{\mathrm{T}}$ is correct, the term $v^{\frac{5}{3}}(v^{\frac{1}{3}}+\gamma)$ must be sensibly so, for it satisfies the volumes on the saturation line and approaches the value v^2 for large values of v. To justify the factor $\frac{1}{\mathrm{T}}$ recourse would naturally be had to volumetric experiments on superheated steam. Since it has been shown in the previous paper, however, that such experiments do not appear reliable, a more roundabout method is necessitated to justify the factor.

We now proceed to obtain the equations for entropy, η, and energy, ϵ. The equations for energy formed by previous writers have all been based on the assumption that either the specific heat at constant pressure or that at constant volume is constant, or on another assumption equally unjustifiable, which will be mentioned later. There will be needed the quantity

$$\psi = \epsilon - \mathrm{T}\eta,$$

and since

$$d\epsilon = \mathrm{T}d\eta - pdv,$$

we have

$$d\psi = -\eta d\mathrm{T} - pdv.$$

From this equation follow

$$\left.\frac{\delta\psi}{\delta v}\right]_{\mathrm{T}} = -p \quad \text{and} \quad \left.\frac{\delta\psi}{\delta \mathrm{T}}\right]_{v} = -\eta.$$

Substituting the value of p from our equation of condition in the first of these, and integrating, there results

$$\psi = -\mathrm{RT}\log_\varepsilon(v-a) - \frac{2\mathrm{A}}{\mathrm{T}\gamma v^{\frac{1}{3}}} + \frac{2\mathrm{A}}{\mathrm{T}\gamma^2}\log_\varepsilon\frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}} + \mathrm{F}(\mathrm{T})$$

where F(T) is some unknown function of T. It should be observed that differences of ψ at constant temperature formed by means of this equation are more accurate than the value of p found by the equation of condition, for an integral cannot have a greater percentage of error than the integrand.

Making use of the equation

$$\eta = -\left.\frac{\delta\psi}{\delta\mathrm{T}}\right]_v$$

there is obtained

$$\eta = \mathrm{R}\log_\varepsilon(v-a) - \frac{2\mathrm{A}}{\gamma\mathrm{T}^2 v^{\frac{1}{3}}} + \frac{2\mathrm{A}}{\gamma^2\mathrm{T}^2}\log_\varepsilon\frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}} - \mathrm{F}'(\mathrm{T}).$$

It is at once evident that here the factor $\frac{1}{\mathrm{T}}$ in the equation for p plays an important role, and this equation, together with the one to be obtained presently for the energy, may have a great error at small volumes, unless the factor $\frac{1}{\mathrm{T}}$ is justified.

From the equation

$$\epsilon = \psi + \mathrm{T}\eta$$

we find

$$\epsilon = -\frac{4\mathrm{A}}{\gamma\mathrm{T}v^{\frac{1}{3}}} + \frac{4\mathrm{A}}{\gamma^2\mathrm{T}}\log_\varepsilon\frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}} + f(\mathrm{T})$$

where

$$f(\mathrm{T}) = \mathrm{F}(\mathrm{T}) - \mathrm{T}\,\mathrm{F}'(\mathrm{T}).$$

$f(\mathrm{T})$, except for an additive constant, is the kinetic energy, or rather such part of it as depends on the temperature alone.

A number of writers have performed this same integration with their p-v-T equation, and have immediately assumed that $f(\mathrm{T})$ is linear in the temperature. We are now in position to show that this assumption is contrary to the experimental data at hand by determining $f(\mathrm{T})$ within certain limits. For, from the equation for ϵ, we have

$$f(\mathrm{T}) = \epsilon + \frac{a}{\mathrm{T}v^{\frac{1}{3}}} + \frac{b}{\mathrm{T}}\log_{10}\frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}}$$

where, if ϵ is expressed in kilogrammeters and v in cubic meters per kilogram, the constants are given by

$$\log a = 6{\cdot}286713 \qquad \gamma = 1{\cdot}20484.$$
$$\log b = 6{\cdot}567998$$

Now ϵ and v are known on the saturation line for values of T from 273°·7 to 473°·7. For there

$$\epsilon = \mathrm{JH} - p(v-w)$$

where H is the total heat, J the mechanical equivalent, and w the volume of water at the pressure and temperature under consideration. Consequently $f(\mathrm{T})$ is found for this range.

The values given for the energy on the saturation line by the last equation are untrustworthy at low temperatures, since there v is rather uncertain owing to the error in Regnault's formula for corresponding saturation pressures and temperatures. But from the equation for p, since for the region below 100° C. w is constantly 0·001, there is obtained

$$p(v-w) = \frac{\mathrm{RT}(v-{\cdot}001)}{v-{\cdot}0008} - \frac{\mathrm{A}(v-{\cdot}001)}{\mathrm{T}v^{\frac{2}{3}}(v^{\frac{1}{3}}+\gamma)}.$$

In the first term of the second member, since v is large, any error in v cancels out. The last term is so small for the region where serious errors in v may occur that the volumes calculated from the latent heats may be used. This also is true concerning the values of the potential energy; any slight errors in the volumes at low temperatures will not affect things.

In this manner ϵ has been calculated for the saturation line, then $f(\mathrm{T})$, and the following table obtained. In the first column is given the absolute temperature, in the second the corresponding value of $f(\mathrm{T})$, and in the third, under $f'(\mathrm{T})$, the average rate of increase of $f(\mathrm{T})$ for each ten degrees.

T	f(T)	f'(T)	T	f(T)	f'(T)	T	f(T)	f'(T)
273·7	242870		343·7	252135		413·7	261362	
		141·5			126·4			146·6
283·7	244285		353·7	253399		423·7	262828	
		137·3			127·0			151·2
293·7	245658		363·7	254669		433·7	264340	
		133·4			127·1			155·7
303·7	246992		373·7	255940		443·7	265897	
		131·4			128·5			159·5
313·7	248306		383·7	257225		453·7	267492	
		128·7			133·4			163·3
323·7	249593		393·7	258559		463·7	269125	
		128·0			137·3			165·2
333·7	250873		403·7	259932		473·7	270777	
		126·2			143·0			

Leaving out the lowest temperatures, which will be considered presently, we have the very remarkable fact that $f'(\mathrm{T})$, instead of being constant, as is generally supposed, is an increasing function of the temperature. Thiesen* in a recent paper has shown that the total energy, expressed as a function of v and T, is not linear in T, but it has never before been shown, so far as the present writer can discover, that the kinetic energy is not linear, although Massieu† has given a complicated proof that the specific heat at constant pressure increases with the temperature; this, indeed, was contemporaneously done by Weyrauch.‡ Regnault§ has found experimentally the same fact for carbonic acid gas.

This fact that $f'(\mathrm{T})$ is an increasing function of T is so important that it is well to speak of the proof more in detail. We have from page 133

$$f(\mathrm{T}) = \epsilon_s - \pi_s$$

ϵ_s and π_s denoting respectively the values of the total and potential energies on the saturation line. At 100° C., 150° C. and 200° C. the values of ϵ_s are 254757, 259571 and 264336 respectively, and if the last number were increased by 49, ϵ_s would be linear in T. On the other hand the corresponding values of $-\pi_s$ are 1183, 3257 and 6441, the zero of potential energy being that of indefinitely rare gas, and the last exceeds a linear formula for π_s by 1110. Now it is impossible that by any change of p-v-T equation, hence a change of the form of π, the number 1110 can be reduced to 49.

We have next a remarkable corroboration of our formulæ, in particular of the factor $\frac{1}{\mathrm{T}}$ in the last term of the p-v-T equation, by means of Regnault's experimental determination of the specific heat at constant pressure. At temperature 403°·7, pressure 760$^{\mathrm{mm}}$, the volume is found by the p-v-T formula to be 1·8018 cubic meters per kilogram. We have then, if Q_1 is the quantity of heat necessary to turn one kilogram of water at 0° C. into this state at constant pressure,

$$\epsilon = \mathrm{JQ}_1 - p(v-w) = \mathrm{JQ}_1 - 18609.$$

But from the formula for ϵ on page 133, since we know (page 134) $f(403{\cdot}7) = 259932$, we have $\epsilon = 258909$, hence $\mathrm{JQ}_1 = 277518$.

Similarly at temperature 473°·7, pressure 760$^{\mathrm{mm}}$, we find the volume to be 2·1314. We thus obtain in the same way

$$\mathrm{JQ}_2 = 292035,$$

Q_2 being the supply of heat necessary to turn one kilogram of water at 0° C. into steam of this second state, at constant pressure.

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* Wied. Ann., 1897, No. 13, p. 329.

† Mem. des Savants Étrangers, vol. xxii, p. 58, 1876.

‡ Zeitschr. des Ver. Deutsch. Ing., xx, pp. 1, 71, 1876.

§ Mem. of the Institute of France, vol. xxvi, pp. 128, 129.

Accordingly, we find for the mean specific heat at atmospheric pressure from 403°·7 to 473°·7

$$C_p = \frac{Q_2 - Q_1}{473·7 - 403·7} = 0·4846$$

or only 0·9 per cent greater than Regnault's mean specific heat at atmospheric pressure from about 401°·7 to 490°·7, namely 0·4805. When one considers that this deviation could be cancelled by a diminution of less than 0·05 per cent in the latent heat at 200° C., which is far within the limits of error, the essential corroboration of the formulæ is evident.

Gray* has attempted to show that Regnault's experiments on the specific heat of superheated steam give a value of 0·3787. He does this by comparing the total heat at 100° C. with the quantities of heat obtained in the experiments on superheated steam. But this is not allowable, as Regnault† himself distinctly states, and he would not even compare the heats in different series of experiments. In fact if the latter be compared some absurd results are obtained.

We have now to express $f(T)$ by a formula. To get as high a determination as possible the writer has taken Regnault's second determination of the mean specific heat at constant pressure, namely that from 138° C. to 226° C. at atmospheric pressure it is 0·48111. Assuming this to be true from 130° to 230°, we obtain the quantity of heat necessary to heat the steam at atmospheric pressure between those temperatures. Adding this to JQ_1 found on page 135 we obtain the quantity of heat necessary to heat water at atmospheric pressure from 0° C. into steam at 230° C., JQ_2. At the latter state the volume is 2·2713, so subtracting $p\,(2·2703)$ from JQ_2 we find the energy at this state. From the energy formula $f(T)$ is found to be 275278.

It will be noticed that at low temperatures $f''(T)$ apparently changes sign. This is entirely dependent on the formula chosen for total heats at those temperatures. In the preceding article, in forming the expression for the total heats from 0° C. to 100° C., it was assumed that since $\frac{d^2H}{dt^2}$ was negative above 100°, it was probably so below. Under this assumption we see $f''(T)$ to change sign. On the other hand, if we make $f''(T)$ of one sign throughout, namely positive, $\frac{d^2H}{dt^2}$ must change sign. Now it is far more probable that the latter does so, for it concerns only a particular set of states, namely those on the saturation line, whereas $f''(T)$ refers to any states whatever. The writer has therefore assumed $f(T)$ to be represented in the range considered, so far as the accuracy of the experiments permits us, by the formula

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* Phil. Mag., xiii, p. 337, 1882.

† Mem. of the Institute of France, vol. xxvi, pp. 165, 166.

$$f(T) = a + bT + cT^2$$

Determining a, b and c from the values of $f(T)$ at 273°·7, 373°·7 and 503°·7, there are obtained

$$a = 215126 \qquad \log b = 1{\cdot}902449 \qquad \log c = \bar{2}{\cdot}894845$$

How well $f(T)$ is represented by this formula is shown by the following set of values calculated from it, which should be compared with those given on page 134. In order to properly represent the inaccuracies of the formula, in the third column are given the fractional deviations in the latent heats which it would be necessary to assume in order to make the formula absolutely correct.

T	$f(T)$	d	T	$f(T)$	d	T	$f(T)$	d
273·7	242870	0	353·7	253200	−·0009	433·7	264536	+·0009
283·7	244107	−·0008	363·7	254562	−·0004	443·7	266023	+·0006
293·7	245358	−·0012	373·7	255940	0	453·7	267527	+·0002
303·7	246626	−·0015	383·7	257334	+·0005	463·7	269045	−·0004
313·7	247910	−·0017	393·7	258743	+·0008	473·7	270580	−·0010
323·7	249209	−·0016	403·7	260167	+·0011	503·7	275278	0
333·7	250524	−·0014	413·7	261608	+·0011			
343·7	251854	−·0013	423·7	263064	+·0011			

It will be noted that the negative deviations near 313·7 bring the latent heats nearer Griffiths' determinations. It is probable that the latent heats thus calculated from $f(T)$ as expressed by the formula are from 0° C. to 100° C. nearer the truth than those obtained from the formula for H given in the preceding article.

Theoretically it would be very gratifying if $f'(T)$, which is the specific heat at constant volume for very large volumes, should at low temperatures approach either 3R or $\frac{5}{2}$R. These are respectively 141·44 and 117·37. That the first is not approached is evident from the numbers on page 134. Whether or not the second is, is not conclusively shown; the total heats are not accurately enough known at low temperatures to determine this. Since $\frac{7}{2}$ R would be 165·01, it looks as though in the range say from −50° C. to +200° C. a change in the molecular deportment of the steam occurs, such that the number of degrees of freedom of the molecule increases, and the specific heat at constant volume changes from $\frac{5}{2}$ R to $\frac{7}{2}$ R. Such molecular change might explain why a difficulty exists in finding a p-v-T formula to satisfy both water and steam.

From the relation

$$f(\mathrm{T}) = \mathrm{F}(\mathrm{T}) - \mathrm{T}\mathrm{F}'(\mathrm{T})$$

there follows

$$f'(\mathrm{T}) = -\mathrm{T}\mathrm{F}''(\mathrm{T})$$

from which F′(T) and F(T) are determined. The formulæ for η and ψ on page 133 become accordingly

$$\eta = a' \log_{10}(v-\alpha) - \frac{b'}{\mathrm{T}^2 v^{\frac{1}{3}}} + \frac{c'}{\mathrm{T}^2} \log_{10} \frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}} + d' \log_{10} \mathrm{T} + e' \mathrm{T} + \mathrm{K}'$$

$$\psi = -a'\mathrm{T} \log_{10}(v-\alpha) - \frac{b'}{\mathrm{T} v^{\frac{1}{3}}} + \frac{c'}{\mathrm{T}} \log_{10} \frac{v^{\frac{1}{3}}+\gamma}{v^{\frac{1}{3}}} -$$

$$d' \mathrm{T} \log_{10} \mathrm{T} - e'' \mathrm{T} - \frac{e'}{2} \mathrm{T}^2 + \mathrm{K}''$$

where if η is in kilogrammeters per degree, ψ in kilogrammeters, and v in cubic meters per kilogram,

$\log a' = 2{\cdot}035657$ $\log b' = 5{\cdot}985683$
$\log c' = 6{\cdot}266968$ $\log d' = 2{\cdot}264662$
$\log e' = \bar{1}{\cdot}195875$ $\log e'' = 2{\cdot}050449$
$\mathrm{K}' = 192{\cdot}2$ $\mathrm{K}'' = 215126.$

These formulæ, with that for the energy, have the same limitations as to pressure and volume as the p-v-T formula, and in addition can be used only when T is not far above 503°·7 or far below 273°·7.

The value of K′ was determined so as to make the entropy correct for the saturation line at 373°·7; the remaining quantities follow from others previously determined. How well the formula for η represents the saturation line is shown by the following table, in the third column of which are given the fractional changes in the latent heats necessary to make the formula for η correct. These should be the same as those given on page 137, but there are differences, very slight, however.

T	η	d	T	η	d	T	η	d
273·7	935·4	+·0011	343·7	788·2	−·0011	413·7	702·5	+·0010
283·7	908·5	0	353·7	773·1	−·0010	423·7	693·3	+·0011
293·7	883·9	−·0007	363·7	759·2	−·0006	433·7	684·4	+·0008
303·7	861·4	−·0011	373·7	746·3	0	443·7	676·3	+·0008
313·7	840·7	−·0015	383·7	734·2	+·0005	453·7	668·5	+·0002
323·7	821·7	−·0015	393·7	722·9	+·0005	463·7	661·3	−·0002
333·7	804·3	−·0013	403·7	712·4	+·0009	473·7	654·5	−·0005

It has been remarked that Regnault's formula for corresponding pressures and temperatures is incorrect at low temperatures. Also Wiebe * has taken exception to his determinations near

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* Zeitschr. für Instrumentenk., xiii, p. 329, 1893.

80° C. There will now be developed a formula for p from the latent heats.

We have from Clausius for the saturation line

$$v - w = \frac{\mathrm{JL}}{\mathrm{T}} \frac{d\mathrm{T}}{dp},$$

from which follows

$$\frac{dp}{p d\mathrm{T}} = \frac{d \log p}{d\mathrm{T}} = \frac{\mathrm{JL}}{\mathrm{T}p\,(v-w)}.$$

Let us denote this by D. We have already obtained $p\,(v-w)$ with great accuracy (page 134) for temperatures below 100° C. For L we take the values from the assumed equation for $f(\mathrm{T})$, which seem to be the best obtainable. Thus D is found for various values of T.

Next the writer has assumed that D is represented by

$$\mathrm{D} = \frac{\mathrm{A}}{\mathrm{T}^2} + \frac{\mathrm{B}}{\mathrm{T}^3} - \frac{\mathrm{C}}{\mathrm{T}^4}.$$

This is Rankine's form, with the addition of the term $\frac{\mathrm{C}}{\mathrm{T}^4}$.

Determining A, B and C from the values of D at 273°·7, 323°·7 and 373°·7, there are found

$\log \mathrm{A} = 3{\cdot}539061 \qquad \log \mathrm{B} = 5{\cdot}826374 \qquad \log \mathrm{C} = 7{\cdot}556878$

How well this represents D is shown by the following comparison. Under D is given the value as first found from the latent heats, and under D′ that according to the formula.

T	D	D′	T	D	D′
273·7	0·0724625	0·0724626	333·7	0·0462057	0·0462064
283·7	0·0667980	0·0667857	343·7	0·0432180	0·0432188
293-7	0·0617441	0·0617298	353·7	0·0405067	0·0405049
303·7	0·0572187	0·0572100	363·7	0·0380399	0·0380322
313·7	0·0531516	0·0531546	373·7	0·0357738	0·0357738
323·7	0·0495038	0·0495037			

Integrating, there is obtained

$$\log_{10} p = -\frac{\mathrm{A}'}{\mathrm{T}} - \frac{\mathrm{B}'}{\mathrm{T}^2} + \frac{\mathrm{C}'}{\mathrm{T}^3} + \mathrm{K}$$

where

$\log \mathrm{A}' = 3{\cdot}176848 \qquad \log \mathrm{B}' = 5{\cdot}163131$

$\log \mathrm{C}' = 6{\cdot}717544 \qquad \mathrm{K} = 7{\cdot}844259$

K is determined by making p equal to 760$^{\mathrm{mm}}$ when T is 373°·7. In the following table the values of p according to this formula are given in the second column, in the third are Regnault's pressures, p_R, in the fourth the fractional deviations of the former from the latter, and in the fifth a few determinations at low temperatures recently made by Juhlin.*

T	p	p_R	d	p_J
273·7	4·626	4·6	·006	4·618
283·7	9·277	9·165	·012	9·242
293·7	17·632	17·391	·014	17·46
303·7	31·943	31·548	·013	
313·7	55·449	54·906	·008	
323·7	92·610	91·980	·007	
333·7	149·40	148·79	·006	
343·7	233·59	233·08	·005	
353·7	354·94	354·62	·003	
363·7	525·56	525·39	·0003	
373·7	760	760	0	

The variations are considerable, but for those at low temperatures an explanation has already been given, and in the middle of the scale they are not more than could be ascribed to Regnault's not correcting his thermometer to the air-thermometer. Above 100° C. Regnault's gives two formulas, one for temperatures according to the air-thermometer, the other for temperatures by his mercurial thermometer; below 100° this is not done, the inference being that corrections were not made. Now Regnault remarks† that at about 50° C. the air-thermometer differs from the mercurial by two-tenths of a degree, which would be sufficient to account for the deviations in that region. The pressures are on the same side of Regnault's as those of Juhlin, and agree well from 80° to 100° with those of Wiebe.

In the following table are given values of various quantities for the saturation line from 0° C. to 100° C. on the basis of the formulæ developed in this paper, and from 100° to 200° from the formulæ adopted in the preceding article. They represent, in the writer's opinion, the best determinations possible with the data at hand. In the first column is given the temperature Centigrade, in the second the heat of the liquid, in the third the total heat, in the fourth the latent heat, in the fifth the pressure, in the sixth the volume, in the seventh the entropy of water, η_w, and in the eighth and ninth the entropy and energy of dry saturated steam, η_s and ϵ_s.

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* Beiblaetter zu Wied. Ann., xviii, p. 736.

† Comptes Rendus, lxix, p. 884, 1869.

t	h	H	L	p	v	η_w	η_s	ϵ_s
0	0	598·9	598·9	4·626	204·97	0	935·4	242851
10	10·0	602·8	592·8	9·277	105·91	15·5	908·5	244072
20	20·0	606·8	586·8	17·632	57·653	30·3	883·9	245297
30	30·0	610·7	580·7	31·943	32·861	44·5	861·4	246524
40	40·0	614·6	574·6	55·449	19·518	58·4	840·7	247749
50	50·0	618·5	568·5	92·610	12·032	71·7	821·7	248966
60	60·0	622·3	562·3	149·40	7·6666	84·7	804·3	250168
70	70·0	626·0	556·0	233·59	5·0333	97·3	788·2	251353
80	80·1	629·7	549·6	354·94	3·3953	109·7	773·1	252515
90	90·2	633·3	543·1	525·56	2·3472	121·7	759·2	253652
100	100·4	636·7	536·3	760	1·6587	133·5	746·3	254757
110	110·5	639·8	529·3	1075·4	1·1973	144·9	733·9	255724
120	120·6	642·9	522·3	1491·3	0·88099	156·1	722·6	256691
130	130·7	645·9	515·2	2030·3	0·65948	167·0	711·9	257649
140	140·9	648·9	508·0	2717·6	0·50152	177·6	702·0	258615
150	151·1	651·9	500·8	3581·2	0·38707	188·0	692·7	259571
160	161·3	654·8	493·5	4651·6	0·30278	198·1	684·0	260517
170	171·6	657·7	486·1	5961·7	0·23982	208·1	675·9	261485
180	181·9	660·5	478·6	7546·4	0·19216	217·9	668·4	262440
190	192·2	663·3	471·1	9442·7	0·15566	227·5	661·4	263394
200	202·5	666·0	463·5	11689	0·12739	236·9	654·7	264336

The unit here for quantities of heat is the specific heat at 15°, pressures are in millimeters of mercury, volumes in cubic meters per kilogram, energy in kilogrammeters (at Paris) per kilogram, and entropy in kilogrammeters per kilogram per degree.

There is a gratifying confirmation of the formulæ given by Dieterici's experimental determination* of the volume at 0° C., which was 204·68 cubic meters. This differs from the value given in the table by only a little over one-tenth of one per cent. When one considers the roundabout way in which the latter was found, the agreement is quite remarkable. Dieterici considers his determination to be correct within one-half of one per cent.

There are one or two interesting points which can be brought forward concerning the deportment of steam over ice. At 0° C. that portion of the energy due to the terms in the formula containing v is only nineteen kilogrammeters, which is entirely negligible compared with the latent heat. Hence for steam over ice we can set

$$\epsilon = f(\mathrm{T}) .$$

Now if G is the latent heat of ice, and K its specific heat, we have

$$\epsilon = \mathrm{JL} - \mathrm{JK}\,(273{\cdot}7 - \mathrm{T}) - \mathrm{JG} - p\,(v - w) .$$

Hence

$$\mathrm{JL} - \mathrm{JK}(273{\cdot}7 - \mathrm{T}) - \mathrm{JG} - p\,(v - w) - f(\mathrm{T}) = 0 .$$

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* Wied. Ann., xxxviii, p. 1, 1889.

Below 273°·7 we can set

$$pv = p(v-w) = \mathrm{RT}.$$

Then, since

$$\mathrm{JL} = \mathrm{T}(v-w)\frac{dp}{d\mathrm{T}} = \frac{\mathrm{T}p(v-w)}{p}\,\frac{dp}{d\mathrm{T}} = \mathrm{RT}^2\,\frac{d\log p}{d\mathrm{T}}$$

we have

$$\mathrm{RT}^2\,\frac{d\log p}{d\mathrm{T}} - \mathrm{JK}\,(273{\cdot}7 - \mathrm{T}) - \mathrm{JG} - \mathrm{RT} - f(\mathrm{T}) = 0$$

Now first suppose that determinations of L below 0° C. are made, or that those above 0° C. are so accurate that an expression for $f(\mathrm{T})$ is obtained for that region which will bear extrapolation below 0° C. Then $\frac{d\log p}{d\mathrm{T}}$ is known and a relation between p and T determined. Conversely, if the relation between p and T below 0° C. is known, $f(\mathrm{T})$ is at once determined, and thence the latent heats.

ART. XV.—*Descriptions of imperfectly known and new Actinians, with critical notes on other species*, III; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College*, No. LX.

Family PARACTIDÆ Hertwig, op. cit., 1882. Andres, op. cit., p. 255, 1884. McMurrich, Proc. U. S. Nat. Mus., xvi, p. 160, Jl., 1893.

Paractidæ + *Sideractidæ* Daniel., 1890.

Paractidæ + *Actinostolidæ* Carlgren, Kongl. Svenska. Akad. Handl., xxv, II, pp. 64, 137, 1893.

Entacmæous actinaria provided with a mesodermal sphincter muscle, but destitute of acontia. Mesenteries usually numerous, nearly always with 12 or more pairs perfect, the number and arrangement not always truly hexamerous. The perfect and larger imperfect mesenteries are usually fertile. Column-wall is usually smooth, sometimes with submarginal plications and solid ridges; rarely with low wart-like elevations or small verrucæ, sometimes capable of attaching sand, etc. No actinobranchs. No acrorhagi. No disk-tubercles.

The mesoglœa of the wall is usually tough and elastic, thin or thick, often parchment-like or subfibrous, in deep-sea forms often thick and coriaceous. Base with an adhesive disk, which is sometimes amplexicaul, embracing permanently the stems of gorgoniæ, etc. Mouth with two siphonoglyphs and numerous lateral folds. Tentacles simple, usually numerous and retractile. Margin generally capable of involution.

This family appears likely to become an extensive one when all the species, whose places in the system are still doubtful, shall have been studied anatomically. At present there is no practical and sure way to distinguish the *Sagartiadæ* from this family except by the presence of *acontia* in the latter, and this is not always a satisfactory test* with preserved specimens. However, the thin, smooth, tough, wall is often a fairly good indication of this family, as is also the large number of perfect and fertile mesenteries, which are usually thin and have feeble and diffuse longitudinal muscles.

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* All the acontia may be ejected and lost by violent contractions, when certain *Sagartiæ* are placed in preservatives, or they may be easily decomposed in poorly preserved specimens. So they are often not to be found in specimens known to have had them in life. On this account it is doubtful whether several of the genera described by Danielssen, 1890, as destitute of *acontia*, belong to *Paractidæ* or *Sagartiadæ*. Of these *Stelidiactis*, *Altantactis*, *Anthosactis*, *Kyathactis*, and *Korenia* are described as having pores or cinclides in the wall (the last has them also in the disk). These genera may, therefore, be sagartians that have lost their acontia. The first three have only 6 pairs of perfect and 'sterile mesenteries, as is often the case in *Sagartiadæ;* the fourth has 20 perfect pairs; the last has 24 perfect pairs; the base is amplexicaul. His *Sideractis* is octamerous, with 16 perfect pairs of very thin mesenteries, partly fertile; tentacles not retractile, 8 inner ones large; sphincter mesodermal. It probably belongs with *Paractidæ*.

This family now appears to include *Paractis*, *Stomphia*, *Actinostola*, *Actinernus*, *Actinolobopsis*,[*] *Pycnanthus*, *? Sideractis*, *Cymbactis* (near *Stomphia*), *Tealidium*, *Paranthus*, *? Paractinia*, *Kadosactis*, *Phelliopsis*,[†] nov. (type *P. Panamensis* V. '69), *Alloactis*, nov. (type *A.*, *excavata* Hert.), *Raphactis*, nov., *Synanthus* Ver., *Ammophilactis*, nov. (type *A.*, *rapiformis* Les.).

The last named genus is remarkable for its small base and for having minute adhesive suckers near the margin. It agrees with *Paranthus* in living buried in sand and in its elongated form.

Raphactis, gen. nov. Type *R. nitida* V.

Paractidæ having a short column, with thin wall and submarginal longitudinal plications, with raised folds or solid ridges of mesoglœa. Sphincter muscle enlarged distally in a thickened portion of the wall, above which the thin wall can be involuted; below this fold the wall may be smooth, or wrinkled, or slightly warty, but without suckers.

Base either broadly expanded, with thin edges, or amplexicaul and embracing permanently stems of gorgoniæ, etc., and in this case the opposite edges of the same or of different individuals unite by sutures.

Tentacles numerous, rather stout, in several rows, retractile. Mesenteries numerous, 12 or more pairs perfect and fertile; some imperfect ones may also be fertile. Stomodæum short. This genus lacks the pores of the disk and wall described in *Korenia*. *Synanthus* Ver. is closely allied in form and habit; it has a smooth wall and only six pairs of perfect, but fertile, mesenteries.

Raphactis nitida, sp. nov. Figures 18, 22.

Base large, either broadly expanded, with thin edges, or else clasping stems of sponges, hydroids, etc., and in the latter case the opposite lobes may unite together in a close suture; it secretes a tough thin cuticle. Column in contraction low and broad, most of its surface smooth and white in alcohol, often somewhat glossy or, in others, with a parchment-like appearance. The infolded summit is strongly plicated. Toward the contracted summit there is a much thickened fold, usually covered with a series of unequal longitudinally convergent, low, rounded, solid ridges, which vary in number and size, and are often lacking or concealed in the smaller examples; in the larger ones about 24 longer, alternating with shorter. Tentacles of moderate size, thick, tapered, blunt, crowded in five or six rows; in the larger specimens sometimes more than 144 in number; the inner are much longer and stouter than the outer ones. The walls of the tentacles are thick, and uniform. In section the column-wall is generally thin, but tough; toward the collar it becomes gradually much thickened and very firm. Sphincter muscle mesoglœal, imbedded in the thick collar, large, diffuse, club-shaped distally. Mouth large, with two broad shallow siphonoglyphs and about 12 to 14 distinct folds on each side. The siphonoglyphs may lie in the direction of the short axis of the body, or the reverse. Mesenteries regularly hexamerous, in more than four cycles, the fifth usually more or less incomplete; 12 pairs are perfect and fertile and in the larger specimens 16 pairs may join the stomodæum near its upper end; many of the smaller imperfect ones of the fourth cycle are also fertile; those of the fifth cycle are very small except close to the disk and basal membranes where they become larger and some bear small gonads close to the disk. No acontia were found. The stomodæum is very short and broad, strongly plicated within. The gonads are small; those of the perfect mesenteries are close to the base. Septal foramina of large size occur at about mid-height of the column. Diameter of column of the larger examples, contracted in alcohol, ·85 inch (20–22^{mm}); of base 1·5 inch (36^{mm}); height of column ·75 inch (18^{mm}).

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[*] This new name is proposed for *Actinoloba* Hert., 1882 (*non* Blainv., 1834.) The type is *A. reticulata* (Dana, sp.) of Patagonia, etc.

[†] This name is proposed for those species of paractids that have been described as *Phelliæ*. on account of the adherent cuticle. They have usually 12 or more pairs of perfect, fertile, and very muscular mesenteries.

Color in life was not noted.

Station 1043, U. S. Fish Com., Str. Albatross, in 130 fathoms off E. coast U. States, latitude of Delaware Bay.

This species has the habit common to many genera and species of deep-sea *Paractidæ* and *Sagartiadæ* of clasping with its base the stalks of hydroids, gorgoniæ, sponges, etc. When the opposite lobes come in contact they unite in a suture.* So, likewise, do the edges of the bases of adjacent individuals, as shown in fig. 18, A, B, C, and fig. 22.

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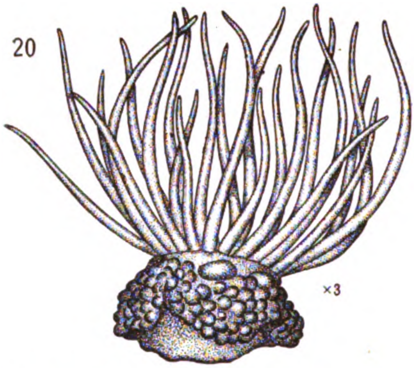
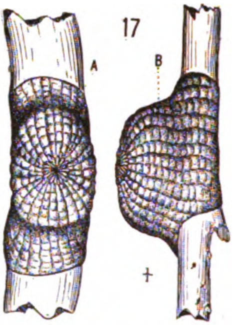
* Hertwig made this habit a generic and family character, in the case of *Amphianthus* and *Stephanactis*, giving it, undoubtedly, an exaggerated importance, for the same species may live either in this way or attached by a broad base to a shell or stone, as I have repeatedly observed in *Actinauge Verrillii* McMur. (= *nodosa* Ver.) and other species. It is even doubtful whether it should be of generic value in any case. *Stephanactis* was used by me in 1868 for a genus near *Discosoma*, consequently I propose for the group thus named by Hertwig the new name *Stephanauge*. It is near *Actinauge* and *Hormathia*. The type, *Stephanauge abyssicola* (Moseley, 1877) is identical with my *Actinauge nexilis* (1883) and came from the same region. *S tuberculata* (Hert.) is very similar, if not the same, but it came from the Pacific Ocean, as did *S. hyalonematis* (McMur., 1883), which last is very imperfectly known The structure of this genus will be discussed later It differs from *Actinauge* chiefly in having the thick wall smooth below the fold, and perforated by distinct cinclides.

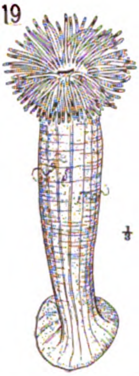
20



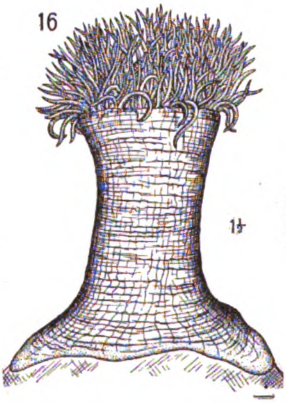
17



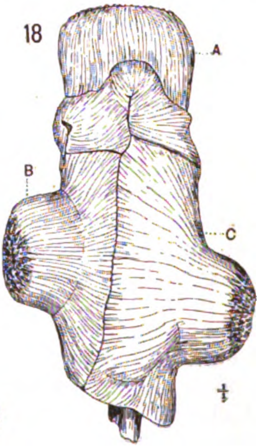
19



16



18



Explanation of cuts.

FIG. 16. *Paractis nivea* (Less.). Peru, × 1½.
FIG. 17. *Raphactis Caribœa* Ver. on a gorgonian, nat. size, front and side view, contracted. West Indies, 124 fathoms.
FIG. 18. *Raphactis nitida* Ver., three examples, A, B, C, natural size, united together by sutures; contracted in alcohol.
FIG. 19. *Sagartia (Psammactis) modesta* Ver., ½ nat. size, from life, New Haven.
FIG. 20. *Viatrix globulifera* D. and M., 1860. × 3. Bermuda.
All the drawings are by A. H. Verrill.

Erratum—In No. II of this series, p. 42, I erroneously referred *Actinia cruentata* Dana to *Bunodactis*, overlooking the anatomical description of McMurrich (Proc. U. S. Nat. Mus., xvi, p. 150, 1893), under the name *Condylactis cruentata*. It should, I now believe, be called *Actinoides cruentata*, as it agrees closely with the typical species of the latter genus. Page 45, *Bunodella stelloides*. Since, the publication of No. II, I have received from Mr. J. E. Duerden, of Jamaica, larger examples of this species. On dissection they were found to have 24 pairs of perfect and fertile mesenteries, thus agreeing with *Bunodactis*. The genus *Bunodella* must, therefore, be dropped, and this species be called *Bunodactis stelloides*. Moreover the name *Bunodella* had already been used by Matthews for a genus of *Eurypteroidea*.

ART. XVI.—*A Volumetric Method for the Estimation of Boric Acid;* by LOUIS CLEVELAND JONES.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXVIII.]

WHEN boric acid and mannite are mixed in solution, a peculiar compound of strongly acid properties is the result. This compound decomposes carbonates, and its acid taste is comparable to that of citric acid, much stronger than that of boric acid alone. Magnanini[*] has found that the product of such a mixture of boric acid and mannite solutions shows greater electrical conductivity and a lower freezing point than a similar molecular solution of either substance alone. Other polyatomic alcohols (but all to a less degree than mannite) and some organic acids show this peculiar property of combining chemically with boric acid to increase its acid qualities.[†] Of this reaction between boric acid and the polyatomic alcohols, Thomson,[‡] Barthe,[§] and Jörgensen[‖] have taken advantage to develop methods for the volumetric estimation of boric acid. Glycerine is used to form a combination with boric acid, sufficiently acidic to give an acid reaction when used with a sensitive indicator and make possible its titration with an alkaline solution. Hönig and Spitz[¶] show that in the method of Jörgensen a very large amount of glycerine must be used to prevent the appearance of the indication of alkalinity with phenolphthalein before all the boric acid is neutralized according to the following equation: $2NaOH + B_2O_3 = 2NaOBO + H_2O$—; that in the presence of carbonates the solution must be boiled to decompose bicarbonates and the escape of boric acid by volatilization prevented by the use of a return condenser, and that silica must be removed by the process of Berzelius, and the solution then neutralized by the use of methylorange before a titration of the boric acid can be made.

Vadam,[**] for the estimation of boric acid in butter, makes use of mannite, which, as he finds, gives sharper indication with litmus than glycerine. According to this process, the solution to be analyzed for boric acid is neutralized by the use of litmus and a solution of sodium hydroxide. Mannite (1–2 grm.) is then added, bringing about an acid reaction with the boric acid present in free condition. The solution is then titrated to alkalinity by sodium hydroxide.

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[*] Gaz. Chim., xx, 428–440, xxi, 134–145.

[†] Klein, J. Pharm. Chim., 4, vol. xxviii; Lambert, Comp. Rend., cviii, 1016–1017.

[‡] J. S. C. I., xv, 432. [§] J. Pharm. Chim., xxix, 163.

[‖] Zeitschr. f. Angew. Chem., 1897, 5.

[¶] Zeitschr. f. Angew. Chem. (1896), 549.

[**] J. Pharm. Chim (6), viii, 109–111.

None of the above methods with glycerine have, in my experience, given anything but comparatively crude results. The weak acidic properties of boric acid, the interference (and difficulty of removal) of carbondioxide with all organic indicators sufficiently delicate to be used with boric acid, and indeed, the procuring of a standard alkali containing no carbonate, together with the supposed detrimental influence of silica and the lack of a convenient method for its removal, have made the process of Gooch,* which involves distillation and weighing with calcium oxide, the only means (though requiring long time and exceeding care) in use for the accurate separation and estimation of boric acid. Recently sodium tungstate has been recommended from this laboratory† as a substitute for calcium oxide to retain the distilled boric acid. The entire process, however, is one of the most exacting in analytical chemistry, and for this reason a convenient, rapid and at the same time accurate method for the estimation of boron is especially desirable. The first step toward the development of such a process must be the convenient preparation and the accurate estimation of the standard solution of alkali to be used for neutralizing the boric acid. This has been found to be easily accomplished by the process recommended by Küsler.‡ This observer, in an extensive investigation of the analytical methods for the volumetric estimation of alkalic and alkali carbonates in solution, finds that both phenolphthalein and methylorange are appreciably sensitive to carbonic acid, but when this interfering agent is removed by precipitation with barium chloride according to the process of Winkler,§ the remaining free alkali may be estimated with great accuracy by phenolphthalein and decinormal hydrochloric acid.

Obviously, if the difficulties dependent upon the action of carbon dioxide can be obviated, and if the acidity of the boric acid can be increased to such an extent that a sufficiently sensitive indicator will give with accuracy the neutralization point with free alkali, and if the alkali and stronger acid can be combined while boric acid alone remains free, then it should be possible to estimate boric acid volumetrically. Experiment has shown that barium chloride removes carbon dioxide, and that mannite makes a combination with boric acid strongly acidic to phenolphthalein.

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* Amer. Chem. Jour., ix, 23–33: Moissan, Comp. Rend., cxvi, 1087: Kraut, Zeitschr. f. Anal. Chem., xxxvi, 165; Montemartini, Gaz. Chim. Ital., xxviii, 1, 344.

† Gooch and Jones, this Journal, vii, 34.

‡ Zeitschr. f. Anorg. Chem, xiii, 124–150.

§ Massanalyse.

To obtain the boric acid alone in free condition many attempts have been made. Gladding,* Thaddeeff† and Rosenbladt‡ have isolated the boric acid by distillation with methyl-alcohol and a non-volatile acid. Many indicators theoretically insensible to free boric acid have been used to indicate the neutralization of the stronger acids. Hönig and Spitz,§ and Thomson,‖ use methylorange, Morse and Burton,¶ tropaeolin 00, while Vadam** makes use of litmus. All these indicators, however, have been found by experiment to be more or less affected by boric acid in solution. On the other hand, I have found in the well-known reaction according to which a stronger acid liberates regularly iodine from a mixture of iodide and iodate, the solution of this difficulty. If both the iodide and iodate are in excess of the acid the entire amount of free acid will be neutralized and the corresponding amount of iodine liberated according to the following equation:

$$5KI + KIO3 + 6HCl = 6KCl + 3H_2O + 3I_2.$$

This liberated iodine may be removed by sodium thiosulphate and a solution obtained which is absolutely neutral containing only neutral salts, potassium iodide, iodate and tetrathionate. The statements made by P. Georgevic†† and Furry,‡‡ that boric acid present in moderate amount in solution has not the slightest action on a mixture of iodide and iodate, have been experimentally verified. Therefore when this acid is liberated by an excess of a stronger acid, and the iodine set free destroyed by thiosulphate, it remains free in solution to be titrated in any convenient manner possible.

Following along the lines suggested by the above reactions, a volumetric process for the estimation of boric acid has been developed. For a basis of the investigations, a standard solution of boric acid was prepared by dissolving in a liter of water about eight grm. of carefully weighed anhydrous boric oxide. This anhydrous boric oxide was prepared from the several times recrystallized hydrous boric acid by long-continued fusion over a blast lamp. A solution of approximately $\frac{n}{5}$ sodium hydroxide was prepared from the ordinary sodium hydroxide of the laboratory. The free alkali in this solution was estimated by the process of Winkler recommended by Küsler. The acid used to make this estimation was hydrochloric, standardised by silver nitrate.

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* Jour. Am Chem. Soc., iv, 568.

† Zeitschr. f Anal. Chem., xxxvi (9), 568.

‡ Zeitschr. f. Anal. Chem, xxvi, 18.

§ Zeitschr. f. Anorg. Chem. (18). 549.

‖ J. S C. I.. xv, 432.

¶ Am. Chem. Jour., x, 154.

** J. Pharm. Chim. (6), viii, 109-111.

†† J. Prac. Chem., xxxviii, 118.

‡‡ Am. Chem. Jour, vi, 341.

The full method for the estimation of boric acid as finally elaborated is as follows: The solution is made clearly acid to litmus by hydrochloric acid and 5^{cm^3} of a solution (10%) of barium chloride added. An amount of iodate and iodide of potassium sufficient to liberate an amount of iodine at least equivalent to the excess of hydrochloric acid in the acidified solution is mixed with starch in a separate beaker, and the iodine, which is usually thrown out by this mixture, is just bleached by a dilute solution of thiosulphate.

To the now neutral solution of iodide and iodate a single drop of the solution to be analyzed is transferred by a glass rod. If a blue coloration is developed, the solution is acidic with hydrochloric acid, and all the boric acid is in free condition. The amount of iodide and iodate used depends upon the acidity of the solution containing boric acid. Usually 10^{cm^3} of a 25 per cent solution of iodide and the same amount of a saturated solution of iodate is sufficient. Any larger excess of hydrochloric acid should be neutralized by sodium hydroxide before the iodide and iodate mixture is added. After the addition of the iodide and iodate solution, containing starch, to the boric acid solution, the liberated iodine should be carefully bleached by thiosulphate. Any excess of thiosulphate in reasonable amount does not seem to be detrimental, but in practice the starch iodide color is clearly bleached, and no more then added. Carbonates prevent a definite indication of the neutral point by thiosulphate and starch iodide, therefore the barium chloride (about 5^{cm^3}) should be added before this point in the process. The mixture of iodide and iodate is not added to the solution to be analyzed until after it is made acidic, for the reason that when the neutral point is approached by the addition of hydrochloric acid, the starch iodide is thrown out locally by the acid, and the small amount of sodium borate remaining undecomposed does not again bleach the coloration produced, thus obscuring the neutral point which must be obtained before titrating for boric acid.

The solution after the bleaching of the iodine by thiosulphate is colorless and contains only starch, neutral chloride, potassium tetrathionate, iodide and iodate, and all the boric acid present in uncombined condition. The carbonate lies out of the sphere of action in insoluble form as barium carbonate. A few drops of the indicator, phenolphthalein, are now added, and the alkaline solution run in until a strong red coloration is produced. A pinch of mannite is then added, which bleaches the phenolphthalein coloration, and the alkali solution again run in to a faint indication, which if permanent on the addition of more mannite, may be taken as the reading point. About 1–2 grm of mannite are necessary for a determination. The boro-mannite compound is sufficiently acidic to liberate iodine abundantly, but it appears to be a time reaction, and at the end of six hours only about 95 per cent of the theoretical amount (considering B_2O_3 as a bivalent acid) has been thrown out. The combination of boric acid and mannite liberates in the presence of iodide and iodate immediately only about one-half the iodine required on the theory that B_2O_3 under these conditions acts as a bivalent acid, or with the neutralizing power of metaboric acid, HOBO. When no mannite is present phenolphthaline gives an alkaline indication when only about one-half the amount of alkali theoretically necessary to form the metaborate, NaOBO, has been added. Obviously, then, the starch iodide coloration will not appear at all on the addition of mannite, if about one-half the free boric acid is first neutralized by the solution of alkali, and the remainder of the alkali immediately added to complete neutralization. The point at which the danger of the appearance of the iodide coloration on the addition of mannite has been passed, is roughly indicated before the mannite has been added by the appearance of the strong alkaline indication of phenolphthalein. This indicator would not need to be added at all, if the boro-mannite compound quickly and regularly liberated iodine from the iodide and iodate. The fact, however, that this compound of boric acid and mannite—as has been ascertained by experiment—liberates, on standing twelve hours, about 99 per cent of the theoretical amount of iodine, places the strength of this acid above that of citric or tartaric acid as investigated by Furry.* With phenolphthalein, however, the end reaction is sharp and the small amount of carbonate present in the standard solution of alkali is precipitated by the barium chloride already in the solution. The calculation must therefore be based on the amount of free hydroxide in the standard solution of alkali used, according to the following representation:

$$B_2O_3 + 2NaOH = 2NaOBO + H_2O.$$

The best results and the most definite indications are obtained in cold solution of a volume not greater that 50^{cm^3}. This fact accords with the observations of Magnanini† that the relative electrical conductivity of the boro-mannite solution is decreased by dilution and elevation of the temperature. When silicates are present in solution, the silicondioxide is liberated by the excess of hydrochloric acid, and this oxide, whether in hydrous or anhydrous condition, neither affects the indication with iodine nor phenolphthalein, nor does it form with mannite a compound of acidic properties. Ammonium salts interfere with the indication given by phenolphthalein and may be removed by boiling with potassium hydroxide in excess, or an indicator used not affected by them.

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* Am. Chem. Jour., vi, 341.

† Gaz. Chim., xx, 428, and xxi, 134.

To test the action of fluorides in the process, several experiments were made in which hydrofluoric acid (10^{cm^3} of $\frac{n}{10}$ solution) was introduced into the solution containing salts of sodium, free hydrochloric and boric acids. Barium chloride was then added and the analysis for boric acid completed in the usual way without the accuracy of the results being in any way interfered with by the presence of hydrofluoric acid.

The following table contains the results of a series of analyses in which the boric acid was first drawn into an excess of sodium hydroxide, then estimated according to the method described.

The standard solutions of boric acid used contained I, 7·153 grm. and II, 7·706 grm. per liter. The solution of free sodium hydroxide was 0·21427 normal.

TABLE I.

		B_2O_3 Sol. taken. cm^3	NaOH Sol. required. cm^3	B_2O_3 taken. grm.	B_2O_3 found. grm.	Errors on B_2O_3. grm.
I.	(1)	21·95	21·02	0·1571	0·1577	+0·0006
	(2)	20·68	19·65	0·1479	0·1474	−0·0005
	(3)	20·73	19·63	0·1483	0·1473	−0·0010
II.	(4)	23·05	23·71	0·1776	0·1777	+0·0001
	(5)	23·10	23·80	0·1780	0·1783	+0·0003
	(6)	22·76	23·35	0·1754	0·1750	−0·0004
	(7)	24·08	24·78	0·1855	0·1857	+0·0002
	(8)	22·00	22·50	0·1695	0·1686	−0·0009
	(9)	20·78	21·28	0·1601	0·1595	−0·0006

Practical tests of the method were made upon specimens of crude calcium borate and colemanite.*

The finely-ground minerals were dissolved in hydrochloric acid and the analyses proceeded with as above described.

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* These specimens were kindly furnished by Dr. C. A. Crampton, of Washington, whom I desire to thank for this courtesy.

Analysis of crude borate of lime.

TABLE II.

	Ca borate taken. grm.	B_2O_3 found. grm.	B_2O_3 in %.
(1)	0·4016	0·2289	56·99
(2)	0·4044	0·2302	56·92
(3)	0·4000	0·2285	57·11

Analysis of Colemanite.

TABLE III.

	Mineral taken. grm.	B_2O_3 found. grm.	% B_2O_3.	
(1)	0·4034	0·2064	51·15	
(2)	0·4070	0·2069	50·80	Average. 50·99%
(3)	0·6004	0·3054	50·86	
(4)	0·6006	0·3056	50·89	
(5)	0·5059	0·2592	51·24	
(6)	0·5092	0·2592	50·89	

An analysis for boric acid by this process can be completed in five minutes and the results are obviously accurate within the limits of ordinary analysis.

The usually interfering substances, fluorine, silica, and carbon dioxide, have no detrimental influence on the results of this process.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Molecular Masses of Gases.*—It has been shown by D. **Berthelot** that in consequence of the difference between the coefficients of expansion and compressibility, the molecular masses of gases are proportional, not to the actual density, but to the product of this value into the molecular volume. The molecular volume of a gas is given by the formula $v_0 = v\frac{p}{p_0}[1+a(p-p_0)] = v\frac{p}{p_0}(1+ap-ap_0)$; in which v is the actual volume under an infinitely small pressure p, p_0 is the normal pressure, and a is a coefficient, constant, according to Regnault between 1 and 6 atmospheres and according to Amagat, below one atmosphere. When p_0 is one atmosphere and p is indefinitely small, the ratio between the molecular volumes of two gases is $v_0/v'_0 = (1-a)/(1-a')$. If their densities be d and d' their molecular masses are proportional to $(1-a)\,d$ and $(1-a')\,d'$. In the table below, the value of a at 0°, the molecular volume v_m at 0° and one atmosphere, the specific gravity d, oxygen being taken as a standard, the molecular mass M when O = 32 and the atomic mass μ when O = 16, are given as calculated:

	H	N	CO	O
a	−0·00046	+0·00038	+0·00046	+0·00076
v_m......	1·00046	0·99962	0·99954	0·99924
d	0·062865	0·87508	0·87495	1·0
M......	2·01472	28·0132	28·0068	32
μ	1·0074	14·007	12·007	16

The author compares the atomic masses of hydrogen, nitrogen, carbon and oxygen deduced as above from the molecular volumes and relative densities, with the best determinations of these values by chemical methods, and shows that they are almost identical.

	O	H	N	C
Physical method,	16	1·0074	14·007	12·007
Chemical method,	16	1·0023—1·0075	14·012	12·001—12·005

It would appear therefore that not only do the values of the atomic masses obtained from relative density and compressibility confirm the results obtained by chemical methods, but that in some cases they may be taken as the more reliable of the two.—*C. R.*, cxxvi, 954–956, 1030–1033, March, April, 1898. G. F. B.

2. *On the Preparation of Metals and Alloys by means of Aluminum.* — The commercial production of aluminum on a large scale has rendered it possible to make use of this metal for the reduction of the oxides and chlorides of other metals.

Experiments by **Goldschmidt** have greatly improved the earlier processes, by showing that it is not necessary to heat the crucible containing the mixture, from the outside, as in a furnace. It is quite sufficient to inflame this mixture at a single point, from which the action spreads more or less quickly throughout the mass. The ignition may be effected by means of a piece of magnesium wire inserted in the mass and lighted by a match. For mixtures of higher igniting points, a primer made by mixing aluminum powder with a substance easily giving up oxygen, such as lead or manganese peroxide, lead or copper oxide, may be placed on the mixture and this inflamed by the magnesium wire. Since the temperature of the reaction is intense, it is best to line the crucible with a refractory material such as magnesia or alumina, or in some cases the oxide of the metal that is to be reduced. The process may be modified by igniting first a small quantity of the mixture in the crucible, and then adding additional portions from time to time. The metals thus obtained are free from carbon and from carbide, and from aluminum also if the oxide is present in excess. In the case of chromium, the temperature reached was found approximately to be 3000°. The fused chromium thus prepared is permanent even in the air of the laboratory, behaving like a noble metal. Fused manganese resembles bismuth, showing surface colors. By this process, alloys of iron with 20 to 25 per cent of boron and with 40 per cent of titanium have been prepared; and also copper containing 10 per cent of chromium. An alloy of lead and barium decomposes water. Sulphides may be reduced in this way and at a lower temperature. The resulting slag when oxides are used is fused alumina, so hard as scarcely to be scratched by the diamond. In preparing chromium, minute transparent red crystals, resembling rubies, are found in it.—*Liebig's Annalen*, ccci, 19, June, 1898. G. F. B.

3. *On the Electrolytic Preparation of Beryllium.*—It has been shown by **Lebeau** that beryllium fluoride, while a non-conductor of electricity when fused, becomes a conductor and an electrolyte when mixed with an alkali fluoride. Two beryllium-sodium fluorides, $BeF(NaF)_2$ and $BeF . NaF$, are available for this purpose. They are most easily prepared by dissolving beryllium hydrate and sodium carbonate, in the required proportions, in hydrogen fluoride and evaporating. The first of these double chlorides fuses at about 350° and the other at about redness. The salt to be reduced is melted in a nickel crucible, acting as the cathode, a rod of graphitic carbon serving as the anode. As soon as the current passes, the external source of heat is withdrawn, the temperature, which should not be allowed to rise above a low red heat, being thereafter maintained electrically. A current of 6 to 7 amperes is required, at an electromotive force of 30 to 40 volts; the metal separating in the crystalline form. If the electrolysis is conducted in a carbon crucible, which contains the other metal in the fused state, and which

serves as the anode, alloys of beryllium may be obtained.—*C. R.*, cxxvi, 744–746, March, 1898. G. F. B.

4. *On Colloidal Silver.*—Some experiments have been made by **Lottermoser** and **von Meyer** on the action of various reagents on colloidal silver. They find that acids precipitate it from solution in the "molecular" state, time and dilution being of great importance. To study the influence of time on the change from the colloidal to the molecular condition, a known amount of acid was added to the colloidal solution and the time was observed which was required for the complete change. By placing a drop of the solution on a glass plate resting on white paper, the end of the reaction is easily detected; the time being noted as soon as the separation of fine silver particles can be readily seen. The results of the experiments are given in a table. They show that the less the amount of acid used the longer the time required for the reaction. Moreover, the amount of acid required to produce the change in a given time appears to be inversely as the concentration of the solution. As to the precipitation of colloidal silver by salts of the heavy metals, experiment shows that where reducible metallic chlorides are used there is formed silver chloride and a lower chloride of the metal; a portion of the silver, however, being always precipitated in the insoluble form. If the solution of colloidal silver and of the metallic chloride are both very dilute, it frequently happens that neither silver chloride nor the lower metallic chloride is precipitated, both remaining in solution in the colloidal form. This behavior is particularly shown by mercuric chloride. Neither the chloride, bromide or iodide of colloidal silver appears to have any application in photography, though the iodide is of interest therapeutically.—*J. pr. Ch.*, II, lvi, 241, 1897; lvii, 540, July, 1898. G. F. B.

5. *On Silver peroxide and peroxynitrate.*—In continuing his researches on the higher oxide of silver and its compounds **Mulder** has observed that when the substance Ag_7NO_{11} is deprived of an atom of oxygen and the residue is extracted with water, silver nitrate goes into solution and silver peroxide Ag_2O_2 remains. Since the silver nitrate can be extracted in a short time, the nitrate Ag_7NO_{11} may be regarded as having the composition $(Ag_2O_2)_3 . AgNO_5$. When boiled with water the peroxynitrate is decomposed, oxygen is set free and silver nitrate goes into solution, leaving a residue of silver peroxide. This suggests a convenient method for preparing the peroxide. This higher oxide dissolves in concentrated sulphuric and in concentrated nitric acid, giving brown solutions. The presence of water accelerates the decomposition of these solutions. The peroxide is not soluble in acetic acid though when diluted silver acetate and oxygen are formed. A method for determining the excess of oxygen in the peroxynitrate is described, based on the decomposition of this salt by water. When kept for some time the peroxynitrate undergoes slow spontaneous decomposition even over sulphuric acid. So slow is this change, however, that the author estimates that it

would require about 13 years to eliminate the two atoms of oxygen in excess.—*Rev. Trav. Chim.*, xvii, 129–176, 1898; *J. Chem. Soc.*, lxxiv, ii, 516, Nov. 1898. G. F. B.

6. *On Neodymium.*—According to **Boudouard**, neodymium can be isolated by allowing a solution of the pure sulphates of the yttrium metals to remain in contact with potassium sulphate in excess for at least 24 hours, then decomposing the insoluble double sulphate thus produced, with sodium hydrate, dissolving the oxide in nitric acid and precipitating with oxalic acid. The substance thus prepared afforded the atomic mass 143, agreeing well with 142·7 ordinarily assigned to this metal. The oxide is greenish, while the oxalate and anhydrous sulphate are slightly rose-colored. The crystallized sulphate, also rose-colored, while less soluble than the anhydrous sulphate, is more soluble in cold water than in hot. A solution of the sulphate gives an absorption spectrum having a shadow from 591·5 to 584, an intense band from 584 to 572, another from 523 to 519, a feeble band from 512 to 508, and faint bands at 480 and 470, due probably to traces of praseodymium. The double sulphate of potassium and neodymium is more soluble than the corresponding compound of praseodymium.—*C. R.*, cxxvi, 900–901, March, 1898. G. F. B.

7. *Leçons de Chimie Physique professées à l'Université de Berlin;* par J. H. **Van't Hoff**, Professeur ordinaire à l'Université, etc. Ouvrage traduit de l'allemande par M. Corvisy. Première Partie, La Dynamique Chimique. 8vo, pp. 263. Paris, 1898 (A. Hermann).—The lectures delivered by Professor Van't Hoff during 1897 were upon "Selected subjects in Physical Chemistry" and were divided into three parts, the first comprising Chemical Dynamics, the second Chemical Statics, and the third Relations between the Properties of Substances and their Composition. The present volume contains the first part only; and like all the productions of this eminent authority, is full of the most valuable material admirably classified and clearly treated. The subject is divided into two principal sections, the first on Chemical Equilibrium and the second on Speed of Reaction; each of these being subdivided into two parts, the former section into Chemical Equilibrium in its Physical and especially its Thermodynamic relations and Chemical Equilibrium in its Mechanical and Molecular relations; and the latter section into Theoretical laws of reaction speeds and Experimental results of Reaction speeds. The translator seems to have done his work with care and thus to have made available this excellent presentation of the subject to a much larger class of students. G. F. B.

8. *Outlines of Industrial Chemistry;* a Text-book for Students. By **Frank Hall Thorp**, Ph.D. 8vo, pp. xx, 541. New York, 1898 (The Macmillan Company).—Dr. Thorp has given us in this book a compendium of commercial chemical processes which cannot fail to be of use to the technical student. The first part is devoted to Inorganic industries such as relate to fuels, waters, the soda industry, the chlorine industry, fertilizers, cements, glass

and ceramics, pigments, etc. The second part treats of Organic industries, connected with the destructive distillation of wood, bones and coal, with mineral oils, with vegetable and animal oils and soaps, with the sugars and fermentation, with explosives, textiles, etc. The volume is well printed and illustrated. G. F. B.

9. *Charge of Electricity carried by the ions produced by Röntgen Rays.*—Mr. C. T. R. Wilson (Phil. Trans. A., 1897, p. 265) has discovered that Röntgen rays can produce a cloudy condensation in dust-free air when the latter is subjected to a sudden expansion. This condensation cannot be produced by expansion without the aid of the rays. Prof. J. J. THOMSON has made use of this phenomenon to determine the value of the product $n\ e\ v$ where n is the number of ions in unit volume of the gas, e the charge in an ion, v the mean velocity of the positive and negative ions under a definite electromotive force. The size of the drops was determined from the expression $v = \frac{2\,ga^2}{9\,\mu}$ in which g is the acceleration of gravitation ; a, the radius of the drop around the ions as nuclei, μ the coefficient of viscosity of the gas through which the drops fell. The velocity was determined by observing the time the top layer of the cloud took to fall a given distance.

The mean value of the charge on the ion was found to be $6{\cdot}5 \times 10^{-10}$. The experiments seemed to show that the charge on the ions in hydrogen was the same as in air. From the laws of electrolysis, if e is the charge on the hydrogen ion in electrostatic units, N the number of molecules in 1 cub. centim. at standard temperature and pressure,

$$Ne = 129 \times 10^{8}.$$

If e is taken as

$$6{\cdot}5 \times 10^{-10}$$

$$N = 20 \times 10^{18}$$

When N deduced from experiments on viscosity of air is 21×10^{18}. The agreement between the value of N got by the kinetic theory of gases by viscosity experiments and the value obtained by Professor Thomson's experiments, leads him to believe that the theory is consistent with the value he has obtained for e, being equal to or of the same order, as the charge carried by the hydrogen ion in electrolysis.—*Phil. Mag.*, Dec. 1898, pp. 528–545. J. T.

10. *Use of the Coherer in Measuring Electric Waves.*—It is still a disputed question whether the coherer can be used in the investigation of stationary electric waves. Professor Murani, of Milan, has published an investigation which seems to show that the coherer is too sensitive to such waves, and that having responded to the first electric impulse it is no longer sensitive to succeeding ones. One thus obtains a more or less constant deflection through a galvanometer in the coherer circuit without any evidence of nodes or ventral segments. O. BEHRENDSEN believes that better results can be obtained by using a comparatively insensitive coherer, which will only respond to the integrated im-

pulses. He makes such a coherer out of comparatively fine carbon powder. By means of such a coherer he obtained evidences of interference phenomena. With a sensitive coherer filled with nickel filings he measured the dimension of electric waves produced by interference in passing through a metallic grating. —*Wied. Ann.*, No. 13, 1898, pp. 1024–1029. J. T.

11. *Color Blindness and the Röntgen Rays.*—E. DORN has investigated the sensitiveness of the eyes of a totally color-blind person to the Röntgen rays. He believes that the light seen by the color-blind person when the eye is exposed to the rays is not due to a fluorescence excited in the retina by these rays, but is due to a peculiar aptitude of the eyes to perceive these rays. The light excited by the rays is greatest at the periphery of the eye; this indicates that the rods of the eye are sensitive to the Röntgen rays. The author then sought to answer the question whether the cones are also sensitive. He discovered that these are also sensitive and no central blind spot insensitive to these rays could be found in the totally color-blind eye. His experiments he believes can be used to disprove the hypothesis that total color-blindness can be ascribed either to failure or the aptitude of the cones of the eye.—*Wied. Ann.*, No. 13, 1898, pp. 1170–1176. J. T.

12. *Regenerating Vacuum Tubes;* by W. ROLLINS. (Communicated.)—In an interesting article in the January number of this Journal on absorption of gases in a high vacuum, Prof. C. C. Hutchins states that after a short period of work the vacuum in a Röntgen tube becomes too high. He then considers the causes of the rise and discusses the various methods for increasing the pressure, recommending oxygen as the most suitable gas because its absorption is slow. The use of oxygen is not new; tubes with adjustable oxygen vacuums were made soon after Röntgen's discovery was announced and were described in a series of notes on Röntgen light in the Electrical Review in 1897–8, and are illustrated in Kirmayer and Oelling's catalogue. In this connection it may be well to state that regenerative tubes with hydrogen vacuums have been recently recommended by Villard, who attaches a closed platinum tube which is heated in a Bunsen flame when it is desired to increase the pressure in the Röntgen tube. A regenerating tube of this kind was described in 1897 in the above-mentioned notes, which was superior to the more recent form, because the hollow platinum tube was used as a target for the impact of the cathode discharge. As this hollow target could be cooled, a large amperage could be used. To increase the pressure it is only necessary to put a drop of liquid hydrocarbon into the hollow target and heat it with the cathode discharge, or illuminating gas can be used, retaining it temporarily in place with a bit of cork.

In some of my experiments I tried a plan used by Professor Trowbridge soon after Röntgen's discovery was announced, but now lost sight of, which consisted in cooling the discharge tube in oil. When this method is applied to a hollow target tube the fresh, cool oil must be made to constantly strike against the back of the target, otherwise this will get red hot and drive back the oil, the hydrogen passing through the platinum. In this way I have had the vacuum change from fifteen inches to one-sixteenth of an inch equivalent air-spark in a short time.

What those of us who are trying to use Röntgen's discovery in medical diagnosis want, is not rediscoveries, but to have placed within our reach apparatus which will convert into Röntgen light an appreciable amount of the energy put into it. At present we may pour in at one end energy at the rate of ten amperes at one hundred volts, and when we come to take it out at the other end as Röntgen radiation there will not be enough with good definition to clearly see through the abdomen. If some broad commercial use could be found for Röntgen's discovery, then the great inventors would attack the problem. At present a tallow candle, notwithstanding its thermic waste, is as a converter of energy into light a shining success compared with the best available Röntgen apparatus. The only notable advance which has been made in practice is due to M. Tesla, but even he seems unable to give much time to this matter; as a result, neither he nor anyone knows when his apparatus will be commercially available. Even when we get it the results will probably be far below the possibilities of the method as shown by the hints dropped from time to time by prominent physicists. Take, for example, Professor Trowbridge's statement that he had made a photograph of the bones of a hand in one-millionth of a second. With the best available apparatus the exposure must be from sixty million to three hundred million times as long. Part of the advance which will be made must consist in devising simple means of making the exciting surges harmonics of the rate of vibration we wish to produce in the radiant energy. All my experiments point in this direction, and I find it practical to get a better result with a small properly-tuned generator than with the largest size improperly adjusted, but I know too little of physics to make any important advance in this matter.

II. GEOLOGY AND NATURAL HISTORY.

1. *The Age of the Earth.*—The January number of the Philosophical Magazine contains a notable article by LORD KELVIN, on the age of the earth as an abode fitted for life. This is an extension of the Victoria Institute Annual Address for 1897. The opening pages give an interesting account of the early attitude of the geologist to the subject in demanding almost unlimited time for the geological changes the earth has gone through and for the development of life. Then follows a summary of the arguments by which the author showed (1862 to 1869) the strict limitations of the possible age of earth, viewed as an abode for life, and arrived at the conclusion that the earth's consolidation

could not have taken place less than 20 million, nor more than 400 million years ago. With respect to this he adds:

"During the 35 years which have passed since I gave this wide-ranged estimate, experimental investigation has supplied much of the knowledge then wanting regarding the thermal properties of rocks to form a closer estimate of the time which has passed since the consolidation of the earth, and we have now good reason for judging that it was more than 20 and less than 40 million years ago; and probably much nearer 20 than 40."

Remarking upon the conclusion reached by Mr. Clarence King (this Journal, Jan., 1893), based largely upon the experimental data supplied by Dr. Carl Barus, in the laboratory of the U. S. Geological Survey, that "we have no warrant for extending the earth's age beyond 24 million of years," he adds that the results of his own recent calculations lead to an estimate not differing much from this.

Going on to discuss the course of events following the first solidification of the earth's surface, the author says:

"§21. I have given strong reasons* for believing that *immediately* before solidification at the surface, the interior was solid close up to the surface: except comparatively small portions of lava or melted rock among the solid masses of denser solid rock which had sunk through the liquid, and possibly a somewhat large space around the center occupied by platinum, gold, silver, lead, copper, iron, and other dense metals, still remaining liquid under very high pressure."

"§22. I wish now to speak to you of depths below the great surface of liquid lava bounding the earth before consolidation; and of mountain heights and ocean depths formed probably a few years after a first emergence of solid rock from the liquid surface (see §24, below), which must have been quickly followed by complete consolidation all round the globe." . . .

"§23. To prepare for considering consolidation at the surface let us go back to a time (probably not more than twenty years earlier as we shall presently see—§24) when the solid nucleus was covered with liquid lava to a depth of several kilometers; to fix our ideas let us say 40 kilometers (or 4 million centimeters). At this depth in lava, if of specific gravity 2·5, the hydrostatic pressure is 10 tons weight (10 million grammes) per square centimeter, or ten thousand atmospheres approximately. According to the laboratory experiments of Clarence King and Carl Barus† on diabase, and the thermodynamic theory‡ of my brother, the late

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* "On the Secular Cooling of the Earth," vol. iii, Math. and Phys. Papers, §§19–33.

† Phil. Mag., 1893, first half-year, p. 306.

‡ Trans. Roy. Soc. Edinburgh, Jan. 2, 1849; Cambridge and Dublin Mathematical Journal, Nov., 1850. Reprinted in Math. and Phys. Papers (Kelvin), vol. i, p. 156.

Professor James Thomson, the melting temperature of diabase is 1170° C. at ordinary atmospheric pressure, and would be 1420° under the pressure of ten thousand atmospheres, if the rise of temperature with pressure followed the law of simple proportion up to so high a pressure."

"§ 24. The temperature of our 40 kilometers deep lava ocean of melted diabase may therefore be taken as but little less than 1420° from surface to bottom. Its surface would radiate heat out into space at some such rate as two (gramme-water) thermal units Centigrade per square centimeter per second.* Thus, in a year (31½ million seconds) 63 million thermal units would be lost per square centimeter from the surface. This is, according to Carl Barus, very nearly equal to the latent heat of fusion abandoned by a million cubic centimeters of melted diabase in solidifying into the glassy condition (pitch-stone) which is assumed when the freezing takes place in the course of a few minutes. But, as found by Sir James Hall in his Edinburgh experiments† of 100 years ago, when more than a few minutes is taken for the freezing, the solid formed is not a glass but a heterogeneous crystalline solid of rough fracture; and if a few hours or days, or any longer time, is taken, the solid formed has the well known rough crystalline structure of basaltic rocks found in all parts of the world. Now Carl Barus finds that basaltic diabase is 14 per cent denser than melted diabase, and 10 per cent denser than the glass produced by quick freezing of the liquid. He gives no data, nor do Rücker and Roberts-Austen, who have also experimented on the thermodynamic properties of melted basalt, give any data, as to the latent heat evolved in the consolidation of liquid lava into rock of basaltic quality. Guessing it as three times the latent heat of fusion of the diabase pitch-stone, I estimate a million cubic centimeters of liquid frozen per square centimeter per centimeter per three years. This would diminish the depth of the liquid at the rate of a million centimeters per three years, or 40 kilometers in twelve years."

"§ 25. Let us now consider in what manner this diminution of depth of the lava ocean must have proceeded, by the freezing of portions of it; all having been at temperatures very little below the assumed 1420° melting temperature of the bottom, when the depth was 40 kilometers. The loss of heat from the white-hot surface (temperatures from 1420° to perhaps 1380° in different parts) at our assumed rate of two (gramme-water Centigrade) thermal units per sq. cm. per sec. produces very rapid cooling of the liquid within a few centimeters of the surface

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* This is a very rough estimate which I have formed from a consideration of J. T. Bottomley's accurate determinations in absolute measure of thermal radiation at temperatures up to 920° C. from platinum wire and from polished and blackened surfaces of various kinds in receivers of air-pumps exhausted down to one tenth-millionth of the atmospheric pressure. Phil. Trans. Roy. Soc., 1887 and 1893.

† Trans. Roy. Soc. Edinburgh.

(thermal capacity ·36 per gramme, according to Barus) and in consequence great downward rushes of this cooled liquid, and upwards of hot liquid, spreading out horizontally in all directions when it reaches the surface. When the sinking liquid gets within perhaps 20 or 10 or 5 kilometers of the bottom, its temperature* becomes the freezing-point as raised by the increased pressure; or, perhaps more correctly stated, a temperature at which some of its ingredients crystallize out of it. Hence, beginning a few kilometers above the bottom, we have a snow shower of solidified lava or of crystalline flakes, or prisms, or granules of feldspar, mica, hornblende, quartz, and other ingredients: each little crystal gaining mass and falling somewhat faster than the descending liquid around it, till it reaches the bottom. This process goes on until, by the heaping of the granules and crystals on the bottom, our lava ocean becomes silted up to the surface."

"*Probable Origin of Granite.*—§ 26. Upon the suppositions we have hitherto made, we have, at the stage now reached, all round the earth at the same time a red hot or white hot surface of solid granules or crystals with interstices filled by the mother liquor still liquid, but ready to freeze with the slightest cooling. The thermal conductivity of this heterogeneous mass, even before the freezing of the liquid part, is probably nearly the same as that of ordinary solid granite or basalt at a red heat, which is almost certainly† somewhat less than the thermal conductivity of igneous rocks at ordinary temperatures. If you wish to see for yourselves how quickly it would cool when wholly solidified, take a large macadamizing stone, and heat it red hot in an ordinary coal fire. Take it out with a pair of tongs and leave it on the hearth, or on a stone slab at a distance from the fire, and you will see that in a minute or two, or perhaps in less than a minute, it cools to below red heat."

"§ 27. Half an hour‡ after solidification reached up to the surface in any part of the earth, the mother liquor among the granules must have frozen to a depth of several centimeters below the surface and must have cemented together the granules and crystals, and so formed a crust of primeval granite, comparatively cool at its upper surface, and red hot to white hot, but still all solid, a little distance down; becoming thicker and thicker very rapidly at first; and after a few weeks certainly cold enough at its outer surface to be touched by the hand."

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* The temperature of the sinking liquid rock rises in virtue of the increasing pressure: but much less than does the freezing point of the liquid or of some of its ingredients. (See Kelvin, Math. and Phys. Papers, vol. iii, pp. 69, 70.)

† Proc. Roy. Soc., May 30, 1895.

‡ Witness the rapid cooling of lava running red hot or white hot from a volcano, and after a few days or weeks presenting a black hard crust strong enough and cool enough to be walked over with impunity.

"*Probable Origin of Basaltic Rock.*[*]—§ 28. We have hitherto left, without much consideration, the mother liquor among the crystalline granules at all depths below the bottom of our shoaling lava ocean. It was probably this interstitial mother liquor that was destined to form the basaltic rock of future geological time. Whatever be the shapes and sizes of the solid granules when first falling to the bottom, they must have lain in loose heaps with a somewhat large proportion of space occupied by liquid among them. But, at considerable distances down in the heap, the weight of the superincumbent granules must tend to crush corners and edges into fine powder. If the snow shower had taken place in air we may feel pretty sure (even with the slight knowledge which we have of the hardness of the crystals of feldspar, mica and hornblende, and of the solid granules of quartz) that, at a depth of 10 kilometers, enough of matter from the corners and edges of the granules of different kinds, would have been crushed into powder of various degrees of fineness, to leave an exceedingly small proportionate volume of air in the interstices between the solid fragments. But in reality the effective weight of each solid particle, buoyed as it was by hydrostatic pressure of a liquid less dense than itself by not more than 20 or 15 or 10 per cent, cannot have been more than from about one-fifth to one-tenth of its weight in air, and therefore the same degree of crushing effect as would have been experienced at 10 kilometers with air in the interstices, must have been experienced only at depths of from 50 to 100 kilometers below the level of the lava ocean."

"§ 29. A result of this tremendous crushing together of the solid granules must have been to press out the liquid from among them, as water from a sponge, and cause it to pass upwards through the less and less closely packed heaps of solid particles, and out into the lava ocean above the heap. But, on account of

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[*] NOTE BY THE EDITOR: An Addendum at the close of the paper quotes the following determination of melting points by Prof. Roberts-Austen:

	Melting-point.	Error.
Feldspar	1520° C.	±30°
Hornblende	about 1400°	
Mica	1440°	±30°
Quartz	1775°	±15°
Basalt	about 880°	

The author adds:

"These results are in conformity with what I have said in §§ 26–28 on the probable origin of granite and basalt, as they show that basalt melts at a much lower temperature than feldspar, hornblende, mica, or quartz, the crystalline ingredients of granite In the electrolytic process for producing aluminium, now practised by the British Aluminium Company at their Foyers works, alumina, of which the melting-point is certainly above 1700° C. or 1800° C, is dissolved in a bath of melted cryolite at a temperature of about 800° C. So we may imagine melted basalt to be a solvent for feldspar, hornblende, mica, and quartz at temperatures much below their own separate melting-points; and we can understand how the basaltic rocks of the earth may have resulted from the solidification of the mother liquor from which the crystalline ingredients of granite have been deposited."

the great resistance against the liquid permeating upwards 30 or 40 kilometers through interstices among the solid granules, this process must have gone on somewhat slowly; and, during all the time of the shoaling of the larva ocean, there may have been a considerable proportion of the whole volume occupied by the mother liquor among the solid granules, down to even as low as 50 or 100 kilometers below the top of the heap, or bottom of the ocean, at each instant. When consolidation reached the surface, the oozing upwards of the mother liquor must have been still going on to some degree. Thus, probably for a few years after the first consolidation at the surface not probably for as long as one hundred years, the settlement of the solid structure by mere mechanical crushing of the corners and edges of solid granules, may have continued to cause the oozing upwards of mother liquor to the surface through cracks in the first formed granite crust and through fresh cracks in basaltic crust subsequently formed above it."

After a further discussion of the probable origin of continents and ocean depths, and also of the earth's atmosphere, the author concludes as follows:

"43. Whatever may have been the true history of our atmosphere it seems certain that if sunlight was ready, the earth was ready, both for vegetable and animal life, if not within a century, at all events within a few hundred centuries after the rocky consolidation of its surface. But was the sun ready? The well founded dynamical theory of the sun's heat carefully worked out and discussed by Helmholtz, Newcomb, and myself,* says NO if the consolidation of the earth took place as long ago as 50 million years; the solid earth must in that case have waited 20 or 50 million years for the sun to be anything nearly as warm as he is at present. If the consolidation of the earth was finished 20 or 25 million years ago, the sun was probably ready,—though probably not then quite so warm as at present, yet warm enough to support some kind of vegetable and animal life on the earth."

"§ 44. My task has been rigorously confined to what, humanly speaking, we may call the fortuitous concourse of atoms, in the preparation of the earth as an abode fitted for life, except in so far as I have referred to vegetation, as possibly having been concerned in the preparation of an atmosphere suitable for animal life as we now have it. Mathematics and dynamics fail us when we contemplate the earth, fitted for life but lifeless, and try to imagine the commencement of life upon it. This certainly did not take place by any action of chemistry, or electricity, or crystalline grouping of molecules under the influence of force, or by any possible kind of fortuitous concourse of atoms. We must pause, face to face with the mystery and miracle of the creation of living creatures."

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* See "Popular Lectures and Addresses," vol. i, pp. 376–429, particularly page 397.

2. *Recent Publications of the U. S. Geological Survey:** ANNUAL REPORTS.—The five parts (making 6 volumes) of the *18th Annual Report* are now complete. All have been noticed excepting the following papers included in parts II and III:

The Triassic Formations of Connecticut, by W. M. Davis. Pt. II, pp. 1 to 192, 20 pls. including folded map and sections.

Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with reference to the occurrence of underground waters, by R. T. Hill and T. W. Vaughan. Pt. II, pp. 193–321, pls. 31.

A Table of the North American Tertiary Horizons, correlated with one another and with those of Western Europe, with annotations, by W. H. Dall. Pt. II, pp. 323 to 348.

Glaciers of Mount Rainier, by I. C. Russell, with a paper on *The Rocks of Mount Rainier*, by G. O. Smith. Pt. II, pp. 349 to 423, pls. 18.

The Age of the Franklin White Limestone of Sussex County, New Jersey, by J. E. Wolff and A. H. Brooks. Pt. II, pp. 425 to 457, with geological map.

A Geological Sketch of San Clemente Island, by W. S. T. Smith. Pt. II, pp. 459 to 496, pls. 13.

Geology of the Cape Cod District, by N. S. Shaler. Pt. II, pp. 497 to 593, pls. 8.

Recent Earth Movement in the Great Lakes Region, by G. K. Gilbert. Pt. II, pp. 595 to 647, pl. 1.

Some Coal Fields of Puget Sound, by Bailey Willis. Pt. III, pp. 393 to 436, 17 pls.

Geology and Mineral Resources of the Judith Mountains of Montana, by W. H. Weed and L. V. Pirsson. Pt. III, pp. 439 to 616, 18 pls. including maps. See this Journal, vol. vi, p. 508, December, 1898.

The Mining Districts of the Idaho Basin and the Boise Ridge, Idaho, by Waldemar Lindgren, with a report on fossil plants by F. H. Knowlton. Pt. III, pp. 619 to 794, pls. 16.

Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado, by C. W. Purington. Pt. III, pp. 745 to 850. The areal geology of this quadrangle is given by Mr. Cross in plate ciii.

The Nineteenth Annual Report (1897–98) will appear in six parts (seven volumes). The report of the Director C. D. Walcott of Part I, pp. 143 with two folded maps, giving an account of the operations of the Survey to June 30, 1898, is already issued. The total appropriation for the work of the Survey was $1,033,963.60. Besides continuing the work already begun along essentially the same lines, this increased appropriation provided for the Survey of Forest Reserves, the boundary line between Idaho and Montana and the extension of work in Alaska. Mineral Resources for

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* Issued since March, 1898. For last complete list and references to earlier ones see this Journal for April, 1898, p. 303; notices published since this date are referred to under the respective titles.

1897, forming Part VI of the Nineteenth Annual Report, will appear in two volumes; the first including Metallic Products, Coal and Coke, the second, Non-Metallic Products excepting Coal and Coke. Separates are nearly all issued and volumes will soon appear.

MONOGRAPHS: Fossil Medusæ Mon. xxx, by C. D. Walcott, pp. 201, pls. 47. See this Journal, December, 1898, p. 508.

BULLETINS: *The Cretaceous Foraminifera of New Jersey*, by R. M. Bagg, Jr. Bull. No. 88, pp. 89, pls. 6.

Some Lava Flows of the Western Slope of the Sierra Nevada, California, by F. L. Ransome, Bull. 89, pp. 73. See this Journal for December, 1898, p. 509.

Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy, by F. B. Weeks, Bull. No. 149, pp. 152, for 1896; Bull. 156, pp. 130, for 1897.

The Educational Series of Rock Specimens collected and distributed by the U. S. Geological Survey, by J. S. Diller, Bull. 150, pp. 400, pls. 47. See this Journal, January, 1899, p. 74.

The Lower Cretaceous Gryphæas of the Texas Region, by R. T. Hill and T. W. Vaughan, Bull. No. 151, pp. 138, pls. 35. See this Journal, January, 1899, p. 70.

A Catalogue of Cretaceous and Tertiary Plants of North America, by F. H. Knowlton, Bull. 152, pp. 247.

A Bibliographic Index of North American Carboniferous Invertebrates, by Stuart Wheeler, Bull. No. 153, pp. 653.

A Gazetteer of Kansas, by Henry Gannett, Bull. No. 154, pp. 246, with map of the State.

Earthquakes in California in 1896 and 1897, by C. D. Perrine, Bull. 155, pp. 45.

WATER SUPPLY AND IRRIGATION PAPERS: No. 12, *Underground Waters of a portion of Southeastern Nebraska*, by N. H. Darton, pp. 56, pls. 21.

No. 13, *Irrigation Systems in Texas*, by W. F. Hutson, pp. 68, pls. 10.

No. 14, *Tests of Pumps and Water Lifts*, by O. P. Hood, pp. 91, pl. 1.

Nos. 15 and 16, *Operations at River Stations in 1897*, Parts I and II, by F. H. Newell, pp. 200.

No. 17, *Irrigation near Bakerfield, California*, by C. E. Grunsky, pp. 96, pls. 16.

No. 18, *Irrigation near Fresno, California*, by C. E. Grunsky, pp. 94, pls. 14.

Geologic Folios: No. 38, Butte Special, Montana, Long. 112° 29′ 30″ to 112° 36′ 42″, Lat. 45° 39′ 28″ to 46° 02′ 54″, by S. F. Emmons and G. W. Tower, Jr.

No. 39, Truckee, California, Long. 120° to 120° 30′, Lat. 39° to 39° 30′, by Waldemar Lindgren.

No. 40, Wartburg, Tennessee, Long. 84° 30′ to 85°, Lat. 36° to 36° 30′, by Arthur Keith.

No. 41, Sonora, California, Long. 120° to 120° 30′, Lat. 37° 30′ to 38°, by H. W. Turner and F. L. Ransome.

No. 42, Neuces, Texas, Long. 100° to 100° 30′, Lat. 29° 30′ to 30°, by R. T. Hill and T. W. Vaughan.

No. 43, Bidwell Bar, California, Long. 121° to 121° 30′, Lat. 39° 30′ to 40°, by H. W. Turner.

No. 44, Tazwell, West Virginia, Long. 81° 30′ to 82°, Lat. 37° to 37° 30′, by M. R. Campbell.

No. 45, Boise, Idaho, Long. 116° to 116° 30′, Lat. 43° 30′ to 44°, by Waldemar Lindgren.

No. 46, Richmond, Kentucky, Long. 84° to 84° 30′, Lat. 37° 30′ to 38°, by M. R. Campbell.

Topographic Folios: Physiographic Types by Henry Gannett. See this Journal for July, 1898, p. 102. J. S. D.

3. *A Catalogue of the Cretaceous and Tertiary plants of North America;* by F. H. KNOWLTON, pp. 1–247, 1898, U. S. Geological Survey, Bulletin 152.—Mr. Knowlton has furnished paleobotanists a valuable aid to study by publishing this working catalogue of the known American species of Cretaceous and Tertiary plants, without waiting to make it absolutely perfect. Systematic names are checked back as far as the Kew Index for genera found also living, and to original source of description for species and the more important references to later descriptions or illustrations. Also the matters of geographical distribution and geological range are given so far as commonly reported in the literature, while the full knowledge regarding these points is left for future investigation.. The Bibliography is a list of the papers consulted without assuming that it is a complete list.

4. *Iowa Geological Survey. Annual Report, 1897, with accompanying papers.* SAMUEL CALVIN, State Geologist, vol. viii, pp. 1–427, plates 1–xxxii, figures 1–13, and six maps, 1898.—This eighth volume contains detailed reports of the areal geology and, where ascertained, the faunal lists of fossil species for the counties of Dallas, Delaware, Buchanan, Decatur and Plymouth, with excellent colored maps and frequent half-tone views of important rock sections and landscapes. H. F. Bain contributes a chapter on Properties and Tests of Iowa Building stones. H. S. W.

5. *A Preliminary Report on a Part of the Gold Deposits of Georgia;* by W. S. YEATES, State Geologist, and S. W. MCCALLIE and FRANCIS P. KING, Assistant Geologists. 1896. Geological Survey of Georgia, W. S. Yeates, State Geologist. Bulletin No. 4-A.—This handsome and well illustrated volume of 542 pages gives an account of the various gold deposits of Georgia, especially with reference to their present development. As is well known, these lie chiefly on lines running northeast and southwest, in the northern part of the State. Some fifty years since, the amount of gold annually coined at the State mint amounted to nearly or quite $500,000; but since the exhaustion of the placer mines, from which most of the gold had been derived, the output has fallen off very largely, and in 1895 the total production of

gold (and silver) is estimated as but $128,000. The geologist, however, expresses the opinion that with the deep-mining and economic working of refractory ores now being introduced, the future outlook is promising, and the production may be expected to reach what it was in former years.

6. *The Report of the Governor of Arizona to the Secretary of the Interior*, for the fiscal year ending June 30th, 1898.—This report, in addition to the discussion of various economic and agricultural subjects of importance especially to the community involved, contains also a detailed account of the distribution of the metallic wealth of the Territory, by W. P. Blake, Territorial Geologist. How varied and extensive the metallic products of Arizona are, is well understood, and this fact gives much interest to this account of the various gold fields, the mines of silver and argentiferous lead, of copper not the least important of the metals, also coal, marble and other mineral products. It is interesting to note that the production of copper in Arizona has been increased fourfold since 1883, and for the first six months of 1898, amounted to nearly 20 per cent of the entire production of the United States.

7. *Die natürlichen Pflanzenfamilien, Lieferung* 182, 183, *Leipzig*, 1898.—Professor ENGLER has carried this important work nearly to completion. The present installments comprise a portion of one of the indexes; a general index is to follow at the close. Certain of the groups of Cryptogams are still in arrears, but they cannot be much longer delayed. The wealth of illustrations, the general treatment of orders, and the skill with which minor references to distribution and use have been employed, make the whole work a treasury for general and special botanists. Under the conditions of publication, it was impossible to avoid the unfortunate separation of subjects which should have been united, but these annoyances are now likely to be forgotten by all the patient subscribers. There cannot be one of these subscribers who does not feel that he has obtained far more than the worth of his money in these clearly printed and attractive volumes.

G. L. G.

8. *The Fishes of North and Middle America.* A descriptive catalogue of the species of fish-like vetebrates found in the waters of North America, north of the Isthmus of Panama; by DAVID STARR JORDAN and BARTON WARREN EVERMANN. Part III, pp. i-xxiv, 2183–3136. Washington, 1898 (Smithsonian Institution: Bulletin of the U. S. National Museum, No. 47).—The third part of this exhaustive Memoir on the Fishes of North America, mentioned on page 79 of the last number, has now appeared. Pages 2183 to 2873 are devoted to the description of species, and the remainder of the volume is given to a key to the families of the true fishes or Teleostei, the glossary of technical terms and the index.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Ostwald's Klassiker der Exakten Wissenschaften.*—The latest additions to this valuable series of scientific classics are Nos. 97 to 103, whose titles are given below. We have often had occasion to call attention to this series before, and its value must now be well appreciated by all of those interested in physics and physical work. It would be difficult to overestimate the importance to the physical student of having before him such papers as are here brought together. They are all of the highest character, and a large part of them, as originally published, are comparatively inaccessible; but they are here republished in convenient form, ready for the student in his study, or the worker in the laboratory. Space forbids any separate notice of the individual memoirs here mentioned, and indeed this is unnecessary, since they are too well known to require it. Ostwald's Series gains additional interest from the fact that an undertaking on somewhat similar lines is being carried forward in this country (already noticed in this Journal), as Harper's Scientific Memoirs, edited by Professor Ames of Baltimore.

Nr. 97. Sir Isaac Newton's Optik oder Abhandlung über Spiegelungen, Brechungen, Beugungen und Farben des Lichts. (1704) II und III Buch.

Nr. 98. Ueber das Benzin und die Verbindungen desselben. Von Eilhard Mitscherlich. (1834.)

Nr. 99. Ueber die bewegende Kraft der Wärme und die Gesetze, welche sich daraus für die Wärmelehre selbst ableiten lassen. Von R. Clausius. (1850.)

Nr. 100. Abhandlungen über Emission und Absorption von G. Kirchhoff.

I. Ueber die Fraunhofer'schen Linien. (1859.)

II. Ueber den Zusammenhang zwischen Emission und Absorption von Licht und Wärme (1859.)

III. Ueber das Verhältniss zwischen dem Emissionsvermögen und dem Absorptionsvermögen der Körper für Wärme und Licht (1860–1862.)

Nr. 101. Abhandlungen über Mechanische Wärmetheorie von G. Kirchhoff.

I. Ueber einen Satz der mechanischen Wärmetheorie und einige Anwendungen desselben. (1858.)

II. Bemerkung über die Spannung des Wasserdampfes bei Temperaturen die dem Eispunkte nahe sind. (1858.)

III. Ueber die Spannung des Dampfes von Mischungen aus Wasser und Schwefelsäure. (1858.)

Nr. 102. Ueber physikalische Kraftlinien. Von James Clerk Maxwell.

Nr. 103. Joseph Louis Lagrange's Zusätze zu Eulers Elementen der Algebra. Unbestimmte Analysis.

2. *University of Tennessee Record of Scientific Engineering.* Published by the University of Tennessee Press, Knoxville, Tennessee.—Number 7 of this publication, for November, 1898, pp. 343–405, has been recently received. It contains a number of original scientific papers, and gives evidence of the scientific activity at the University of Tennessee. Among the papers we notice one on Nutrition Investigations, by Charles E. Wait; several papers on Chemical Analytical Methods; another on Meteorological Observations by means of Kites, by W. M. Fulton; also, Notes on the Flora of West Tennessee, by S. M. Bain.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XVII.—*Studies in the Cyperaceæ;* by Theo. Holm. IX. The genus *Lipocarpha* R.Br. With nine figures in the text, drawn by author.

The genus *Lipocarpha* was established by Robert Brown upon some plants, which were formerly enumerated by Vahl as species of *Hypælyptum.* This latter generic name was, however, a corruption of "*Hypolytrum*" a genus of Richard, and since Vahl had included certain species under this, which did not exhibit the generic character of *Hypolytrum* as understood by Richard, Robert Brown transferred these to his new genus *Lipocarpha:* *L. argentea*, *L. sphacelata* and *L. filiformis.*

As regards the derivation of the name *Lipocarpha*, this is not, as stated by American authors, derived from "λίπος fat and κάρφος chaff, from the thickness of the inner scales of some species," but from "λίπω fall off, drop," "from the whole of its squamæ being deciduous" as already stated by Robert Brown in the Botany of Congo; furthermore the inner scales are never "fat" but constantly membranaceous in the species of *Lipocarpha*, hitherto known. *Lipocarpha* is a small genus, containing only seven species according to Bentham and Hooker, six of which are described by Bœckeler; in later years four more species have been recorded from West Africa by Ridley. While the genus is chiefly tropical, *L. maculata* extends as far north as Virginia, and *L. Sellowiana* as far south as Buenos Ayres. The habit of the species is much the same, reminding one of *Kyllinga*, and they seem to prefer damp or periodically inundated ground. Considered from a morphological view point, our genus possesses a main inflorescence composed of a few short and almost roundish spikes, surrounded by long, green involucral leaves. Each spike bears a number of spirally arranged bracts, inside of which are two minute, membranaceous scales, which surround a flower. The position of these inner scales is somewhat singular, being mediane, the lowest one being situated on the posterior face of rhacheola, the upper one on the anterior face or a little distance above the supporting bract. Both of these scales are hyaline, nearly equal in length and apparently of the same shape, but only the anterior supports a flower. The question is then to decide whether we have "a one-flowered spikelet" or "a single flower" before us, and this is a point that has always been so much disputed.

It would seem most natural, however, to define the two scales and the flower as constituting a one-flowered spikelet, wherein the lower scale would represent the prophyllon of the rhacheola and the upper one the bract of the flower. The position of the lower scale corresponds exactly with that of a true prophyllon in other *Cyperaceæ.* Furthermore its anatomical structure shows us two prominent stereome-bundles and a distinct bicarinate outline, in contrast to the upper scale, the bract, in which we have observed a mediane mestome-bundle, corresponding with other bracts. The accompanying diagram of a spikelet of *L. maculata* shows us the supporting bract (B), in the axil of which is developed a rhacheola with a dorsal prophyllon (P) and a bract (*b*), which supports the naked flower. This explanation seems to us the most natural, when we consider the minor inflorescences of other Cyperaceæ, where the rhacheola is often provided with a basal, empty prophyllon, bicarinate or tubular as in *Carex*, *Cyperus*, *Dulichium*, *Fuirena* and others. Although Robert Brown did not define the lower scale as a prophyllon, he considered, at least in his Botany of Congo,* the minor inflorescence of *Lipocarpha* as a spikelet, not as a single flower, a suggestion that was, also, followed by Kunth, Torrey, Bœckeler and apparently by Baillon. Other authors have held the opinion that there is "a single flower" instead of a spikelet, for instance: Vahl, Nees von Esenbeck, Liebmann, Michaux, Bentham, Ridley, Gray, Schumann, Pax and Goebel. Pax describes the flower as possessing two prophylla: "eine hermaphrodite mit zwei medianen Vorblättern versehene

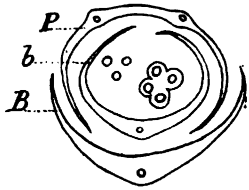

FIG. 1. Diagram of spikelet of *L. maculata.* Explanation in the text.

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* For references consult the bibliography appended to this article.

Blüte," while Goebel, in his interesting paper on some *Cyperaceæ* from Java, considers the flower as possessing only one prophyllon, but is uncertain as to the definition of the other scale: "Jede Blüte besitzt zwei Schuppen, das eine derselben wird als Vorblatt zu bezeichnen, das andere ist mir unklar geblieben."

As regards the flower itself, we have noticed only one stamen in *L. maculata* and two, seldom three stigmata; purely pistillate flowers with rudiments of a stamen were, also, observed. In this respect *L. maculata* agrees with *L. argentea*, as described by Goebel, with the exception that the anther of the stamen in this last species was observed to be two-celled instead of four-celled, as we invariably noticed in *L. maculata* and *L. microcephala*. Concerning the systematic position of our genus with its "mediane scales" and "one-flowered spikelets," it seems that Robert Brown was justified in separating it from Richard's *Hypolytrum*, the flower of which is generally described as possessing "two lateral prophylla." It is difficult at present to point out the nearest allies to our genus, considering that it shows some affinities to *Hemicarpha*, as suggested by Pax in his treatment of this group for Engler's and Prantl's work upon the natural families. Further researches on the morphological structure of the other genera may possibly assist us in determining its correct place within the order, especially when combined with such peculiarities as may be observed in the anatomical structure. In this last respect *Lipocarpha* is very interesting, and in order to make our study as complete as possible, we shall briefly discuss some of the most important features, which we have observed in *L. maculata* Kth. from subtropical Florida, *L. argentea* R.Br. from Nilagiri in Eastern India and Hongkong, *L. sphacelata* R.Br. from the Isthmus of Panama and *L. microcephala* Kth. from Japan.

The stem above ground,

the scape, is cylindrical and more or less furrowed in the species examined. The cuticle is thin and perfectly smooth. The epidermis is here developed into several strata (from two to four) between the subepidermal bundles of stereome. A considerable variation is to be noticed in the outer epidermis, as regards the thickening of the outer cell-walls and the lumen of the individual cells. Thus we find a strongly thickened epidermis in *L. argentea*, but one with very thin walls in *L. microcephala*. The epidermis-cells above the stereome are usually smaller than those surrounding, and contain the characteristic silicious cones, which we have often described in our previous papers on this order. These cone-bearing cells are

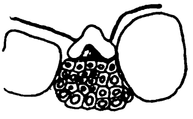

FIG. 2. A cone-cell above the stereome from epidermis of the stem of *L. maculata.* × 400.

thin-walled in *L. maculata* and form a projection in the shape of a minute papilla (fig. 2), while no other epidermal projections were observed in any of the species examined. The outer epidermis-cells, which lie between the stereome-bundles, are very large and round in transverse sections except in *L. argentea*, in which the radial walls have become stretched so as to render the lumen narrow. It is, also, to be noted that the epidermis in *L. argentea* forms very prominent ribs on each side of deep furrows in which the stereome is located. Similar, but more shallow, furrows are also noticeable in *L. maculata* and *L. sphacelata* above the stereome. In *L. microcephala*, however, furrows are, also, present, but the adjoining projecting ribs are not here due to the increased size of epidermis, but to the stereome. These species of *Lipocarpha* thus illustrate a singular variation regarding the location of the stereome: being situated in furrows as in *L. maculata*, *L. sphacelata* and *L. argentea*, or in the projecting ribs in *L. microcephala.* The presence of similar furrows in the stem has, also, been mentioned by Rikli in *Ficinia*, *Fuirena*, *Heleocharis* and others; the stereome, according to this author, is located in furrows in *Heleocharis geniculata* R.Br. and *Fuirena*, but located in the projecting ribs in *Ficinia stolonifera* Nees and *F. tenuifolia* Kth. The interior layers of epidermis show a very uniform structure and the walls are very thin. Stomata are present and form longitudinal rows between the stereome-bundles; they are slightly projecting and the air-chamber is deep and narrow. In this manner they are freely exposed in our species with the exception of *L. microcephala*, where they occupy the deep furrows between the projecting bundles of stereome.

As regards the mechanical tissue, the stereome, this is very well represented in the stem of our species, forming relatively large bundles on the leptome-side of the outer mestome-bundles or on the hadrome-side of the inner ones. In the first case the stereome-bundles are situated immediately underneath the epidermis and border inwards on the chlorophyll bearing palisade-sheath, that surrounds the mestome-bundles. It is generally thick-walled in our species, especially in *L. argentea* and *L. sphacelata.* When considered in transverse sections, the stereome forms roundish groups on the leptome-side of the peripherical mestome-bundles, where it is usually thick-walled; the stereome, that supports the inner mestome-bundles, is, on the other hand, thin-walled and forms an arch around the hadrome of each bundle. *Lipocarpha* thus possesses a well developed stereome, which accompanies the mestome-bundles, but without developing as a continuous ring outside or between these bundles.

In proceeding to examine the assimilating tissue of the stem, we notice in *Lipocarpha* a structure which is very different from that of other genera, discussed in our former papers: *Carex*, *Dulichium*, *Fuirena*, *Dichromena* and *Scleria*.* This divergence consists in the very regular arrangement of the palisade-cells radially around the peripherical mestome-bundles. In the other genera, previously described, the palisade-cells were not arranged radially in proportion to the mestome-bundles, but in proportion to the cross-section of the stem itself. We notice, therefore, in Lipocarpha that each of the outer mestome-bundles is surrounded by a closed sheath of palisade-cells, all of which contain an abundance of chlorophyll-grains. A similar sheath of palisade-cells is, also, observed on the leptome-side of the inner mestome-bundles, adjoining the arch-shaped group of stereome on the hadrome-side. The inner mestome-bundles are, hence, surrounded partly by palisade-cells and stereome. In no other part of the stem is palisade-parenchyma observable, as the spaces between the outer mestome-bundles are occupied by the several layers of epidermis.

While this singular arrangement of the palisade-cells in the stem of *Lipocarpha* seems to offer an excellent character by itself, it is, nevertheless, invariably followed by another and still more remarkable feature, represented by the structure of the mestome-bundles. We have already mentioned that the stem possesses two distinct, concentric bands of mestome-bundles, an outer and an inner. The majority of the mestome-bundles are situated in the peripherical band and represent two forms: small and in transverse section orbicular, and larger which are oval in cross-section. The orbicular are the most abundant, but they do not all possess a leptome and hadrome developed to the same extent as the larger, the oval bundles, nor are they all supported by subepidermal stereome, as these invariably are. Those of the inner band are all large and show a very pronounced oval outline; besides this, they are only supported by stereome on their hadrome-side. But all these mestome-bundles, the large and the small, show the presence of a typical mestome-sheath, the cells of which are but slightly thickened in those species which we have had an opportunity to examine. Inside the mestome-sheath is still another sheath, the cells of which are conspicuously larger than those of the mestome-sheath, very thin-walled and filled with chlorophyll. However the chlorophyll in this sheath differs in a very marked degree from that of the palisade-tissue by not being differentiated as "grains," and by its more intense green color. This is the sheath which Haberlandt has mentioned as characteristic of *Papyrus cicuta*, and which Rikli has so excellently described after he detected it in other genera of the *Scirpoideæ.* While Duval-Jouve was well aware of the radial arrangement of the palisade cells around the mestome-bundles in several species of *Cyperus*, as his illustrations show, he does not seem to have noticed the inner sheath, the "chlorophyll-sheath," at least he does not figure or mention it.*

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* This Journal, vols. iii, iv, v and vi.

While the chlorophyll-sheath is completely closed in all the peripherical mestome-bundles, which, as stated above, are also surrounded by an uninterrupted sheath of palisade-cells, it merely occurs around the leptome in the mestome-bundles of the inner band. We remember from the above that these bundles are not surrounded by palisade-cells excepting on their leptome-side, and it seems as if the development of the inner, "the chlorophyll-sheath," is somewhat depending on the presence of palisade-cells; at least the chlorophyll-sheath is strictly confined to that part of the mestome, which is, also, surrounded by palisade-cells. These structural peculiarities: the development of the assimilating tissue into sheaths around the mestome-bundles and accompanied by an inner chlorophyll-bearing sheath, does not seem to depend upon any particular mode of growth, if we merely consider the stem. We have noticed this same structure in cylindrical as well as in triangular stems of certain genera of *Cyperaceæ*, in erect as well as in curved, besides in the singular flattened stems of *Fimbristylis autumnalis* R. et S. It seems, therefore, hardly probable that the presence of these sheaths depends on any particular position of the stems in proportion to the light, and by comparing leaves of various genera no apparent connection seems to exist between their presence and the shape or direction of the leaf-blades. The genus *Fimbristylis*, for instance, on which the writer has prepared an article for this Journal, exhibits a most remarkable variation of growth as regards stem and leaf, yet invariably possessing the same arrangement of the palisade-cells and development of the inner chlorophyll-bearing sheath.

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* Professor Warming (Halofyt-Studier, p. 259) insists that Duval-Jouve, not Haberlandt, should have credit for the discovery of these peculiar sheaths, stating that Duval-Jouve in the year 1875 described and illustrated these as characteristic of a number of *Gramineæ.* However, the chlorophyll-sheath, the one that lies close up to the mestome-sheath and which borders immediately on the leptome and hadrome, has so far never been observed in any of the *Gramineæ.* What Duval-Jouve describes and figures is a sheath of palisade-cells, a parenchyma-sheath, that surrounds the mestome-bundles and finally a mestome-sheath, inside of the parenchyma-sheath. But in none of his descriptions or in his illustrations has Duval-Jouve hinted at the existence of a chlorophyll-sheath inside of the mestome-sheath. It is true, that the mestome-bundles in the leaves of several *Gramineæ*, for instance *Cynodon*, exhibits three sheaths: one of radially arranged palisade-cells, a second the ordinary parenchyma-sheath, and a third the mestome-sheath, but none of these correspond with the sheath which Haberlandt detected inside of the mestome-sheath in certain *Cypereæ*, and which Rikli has lately discussed in his very important paper on this subject. Furthermore Professor Warming states, that although Duval-Jouve did mention and figure the palisade-sheath as characteristic of several French *Cyperus*-species and *Galilea*, he, nevertheless, seemed to have overlooked the inner one "the chlorophyll-sheath" of Rikli.

While the mere question of priority is a very unimportant one in scientific research, it must be admitted that Haberlandt was the first to discover this particular sheath in the *Cyperaceæ.*

Whether the radial arrangement of the palisade-cells around the mestome-bundles is beneficial to the plant, is a question that cannot be settled at present. It is, also, very uncertain whether the dark, green chlorophyll of the inner sheath possesses a higher assimilating power than that surrounding; very diverse opinions have been expressed regarding these questions, and a brief summary may be found in the work of Warming, cited above.

In returning to the stem-structure of *Lipocarpha*, the leptome and hadrome have attained their highest development in the inner mestome-bundles, but are not, in any of the species we have examined, separated from each other by thick-walled mestome-parenchyma, as described by Rikli (*L. argentea*). There is, furthermore, a large, solid pith which is composed of thin-walled cells, hexagonal in transverse section, in *L. sphacelata* and *L. maculata;* in *L. argentea* and *L. microcephala*, on the other hand, we noticed the pith to be interrupted by large and apparently very irregular lacunes. Cells containing tannin were observed in the pith, close to the mestome-bundles.

Very different is the structure of rhachis, that part of the stem which bears the spikelets. The bark-parenchyma contains no chlorophyll and forms a broad ring around the central-cylinder; the mestome-bundles are mostly small and surrounded by a typical, colorless parenchyma sheath and a thin-walled mestome-sheath, while the inner sheath is totally absent. The arrangement of the mestome-bundles is, also, different, there being a closed band near the center of the axis, while a few are seen to be scattered towards the periphery, entering the rhacheolæ of the spikelets. The rhachis seems totally destitute of stereome and the solid pith occupies only a small part of the central-cylinder. Furthermore we observed that tannin was present in some of the pith-cells as well as in the bark-parenchyma.

The leaf.

The stem-leaves of the species of *Lipocarpha*, which have been examined, are rather weak, with narrowly linear blades, closed tubular sheaths, but no ligule. The margins of the blade are mostly involute, and the blade, which is often very asymmetric, is not carinate. The outline of the blade, when considered in transverse section, is broadly crescent-shaped in *L. maculata* with the two halves of unequal size (fig. 3). The same is, also, the case with *L. argentea*, but the blade is, in this species, constricted above the midrib and is thinner in proportion to its width than in the foregoing species (fig. 4). The blades of *L. microcephala* and *L. sphacelata* are less asymmetric and equally thin throughout. The epidermis of the lower surface of the leaf-blade shows the same development as in the stem with a single layer outside the mestome-bundles and two or three rows of cells between these. But on the upper face of the blade in *L. argentea* and *L. maculata* we find a huge mass of epidermal tissue in layers of considerable width, from five to six, especially towards the margin; in *L. microcephala* and *L. sphacelata*, on the other hand, there is but one single layer on either face of the blade. In considering *L. maculata* and *L. argentea* the outer layer of epidermis consists of much smaller cells than the inner ones, especially towards the margins, where two or three subepidermal stereome-bundles are located. While the outer epidermis in *L. argentea* is developed as bulliform cells above the midrib (fig. 4), where no inner layers are developed, we notice in *L. maculata*, on the same place, a tendency of the outer epidermis to develop in the same way, as bulliform cells, but are separated from the mesophyll by at least two layers of inner epidermis. In the

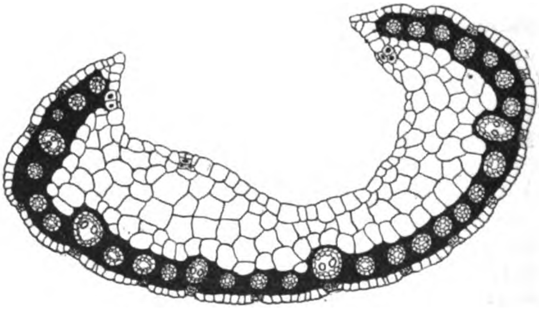

FIG. 3. Leaf of *L. maculata*, transverse section. × 60.

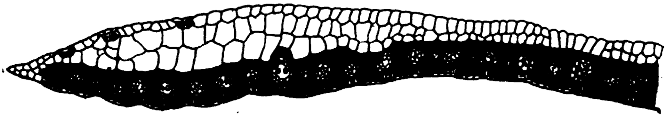

FIG. 4. Part of leaf of *L. argentea*, transverse section. × 60.

two other species the epidermis of the upper face consists of a single layer of cells of almost equal size, but does not seem to develop as groups of bulliform cells, so commonly observed in other genera. The epidermis of the lower surface of the leaf is composed of cells of nearly equal width excepting those which cover the stereome; these are usually much smaller and contain cones of silica. While the lower surface is very even in *L. maculata* and *L. argentea*, we noticed in the two other species distinct furrows between the stereome-bundles like those described above as characteristic of the stem. The stomata are located at the bottom of these furrows, while in *L. argentea* and *L. maculata* they are freely exposed, being on a level with the surrounding epidermis. As regards the mesophyll, this is developed as a sheath around each mestome-bundle, separating these from the stereome of the leptome-side. Thus there exists a strong analogy in structure when we compare the bark of the stem with the mesophyll of the leaf, besides this the mestome-bundles in both show an absolutely identical composition. The mestome- and chlorophyll-sheath are developed to the same degree we noticed in the stem, and the mestome-bundles are, also, here represented by two forms: orbicular and oval, when considered in transverse sections (fig. 5).

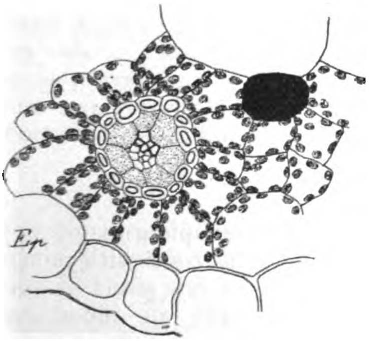

FIG. 5. Leaf of *L. maculata*, showing an orbicular mestome-bundle with its three sheaths; tannin in a cell drawn with black; *Ep.* = epidermis of lower surface. ×400.

Stereome is developed outside the larger mestome-bundles on the lower surface of the blade, but occurs, also, in one or two isolated groups on the upper face and close to the margin. The margin itself merely consists of the two layers of epidermis with no support of stereomatic tissue.

The bracts,

which subtend the spikelets, are membranaceous and contain only one mestome-bundle, located in the middle and forming a slightly projecting rib on the dorsal face. There is an epidermis of large and thin-walled cells on both faces of the bract, with the exception of the margins, where only one stratum of epidermis is developed. A few of the cells contain tannin, but no chlorophyll. The mestome-bundle is surrounded by a single sheath, a mestome-sheath, the cell-walls of which are but very slightly thickened. Stereome is present and forms isolated bundles on the lower surface, one near the midrib, and two on each side, a short distance from the margins.

The prophyllon

of the spikelet shows a very simple structure, there being no mestome but merely about five ribs of stereome, two of which are larger than the others so as to render the leaf bicarinate. Epidermis is developed on both faces excepting near the margins, where it becomes reduced to one single layer. The epidermal cells are very thin-walled, and none are developed as bulliform cells.

The bract

of the flower shows nearly the same structure as that of the spikelet, but much thinner (fig. 6). The epidermis is reduced to a single layer in the lateral parts, from the midrib to the margins, while the margins themselves possess a double epidermis. Stereome is present, but only on the dorsal face of the scale covered by epidermis, and tannin-reservoirs were observed in some of the epidermal cells, indicated with black in the accompanying figure (fig. 6).

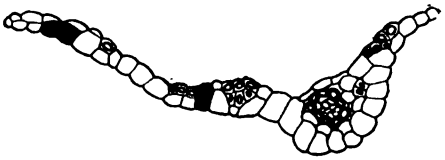

FIG 6. Transverse section of a floral bract of *L. maculata*, showing the midrib and half of the blade; cells containing tannin are drawn with black. ×320.

The pericarp

consists of three distinct layers: an outer epidermis of very thin-walled cells, each containing a silicious cone with minute warty surface, a few strata of sclereids, and finally an inner epidermis. The cells of the inner epidermis are very thin-walled and show a rectangular outline in transverse sections (fig. 7). A skeleton of silica is readily obtained by the usual preparation, and shows that not only the cones are silicified, but also a part of the epidermis above these (figs. 8 and 9).

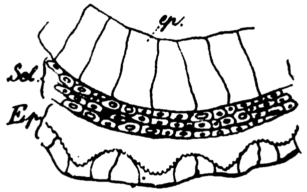

FIG. 7. Transverse section of the pericarp of *L. maculata*. Ep = the outer epidermis; Scl. = the layers of sclereids; ep. = the inner epidermis. ×560.

The roots are very slender and show a rather open structure.

There is a thin-walled hypoderm underneath the epidermis, and the bark is traversed by lacunes of considerable width. The endodermis has the cell-walls thickened all around, representing an O-endodermis, inside of which is a pericambium interrupted by proto-hadrome. The innermost part of the root is occupied by a thick-walled conjunctive tissue with a single or sometimes two large vessels in the center.

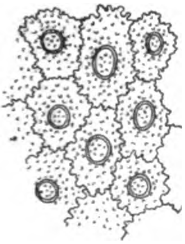

FIG. 8. Epidermis of pericarp of *L. maculata*, seen from above, showing the silica-skeleton. × 560.

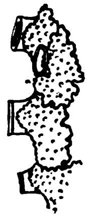

FIG. 9. Same as figure 8, but seen from the side. × 560.

In considering the anatomical structure of these four species of *Lipocarpha*, it seems that our genus possesses several characters by which it may be distinguished from a number of the other genera, studied so far. The species themselves, may, also, be recognized in this way, their anatomical characters being as follows:

The leaf.	Outer cell-walls of epidermis very thin.	Outer cell-walls of epidermis strongly thickened.	Outer cell-walls of epidermis moderately thickened.	Subepidermal stereome in furrows.	Subepidermal stereome forming projecting ribs.	Bulliform cells above midrib.	No bulliform cells.	Epidermis of several layers on upper face.	Epidermis of a single layer on upper face.
L. maculata	−	−	+	+	−	−	+	+	−
L. argentea	−	+	−	+	−	+	−	+	−
L. sphacelata	−	−	+	+	−	−	+	−	+
L. microcephala ...	+	−	−	−	+	−	+	−	+

If we finally compare these anatomical characters with those which Rikli observed in *L. argentea*, we will notice a few divergencies. This author states, for instance, that the leaf possesses one mediane and numerous lateral groups of bulliform cells, while the leaves we examined showed only one, above the midrib (fig. 4); besides that the lateral parts of the blade were covered by several layers of large-celled epidermis. Furthermore is stated that the leptome and hadrome are separated from each other by a zone of thick-walled cells (mestome-parenchyma), which we did not notice in any of the species examined. It seems as if the leaf, which Rikli described, may not have belonged to *L. argentea*, and perhaps not to *Lipocarpha* at all. It is, also, to be pointed out that not all of the *Cyperaceæ*, in which a chlorophyll-sheath is developed, have a scarcity of stereome, since this tissue is well represented in the species of *Lipocarpha.*

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ART. XVIII.—*The Granitic Breccias of Grizzly Peak, Colorado*; by GEORGE H. STONE.

GRIZZLY PEAK is situated about twenty-three miles southwest of Leadville, and forms the watershed from which streams flow northwest into the Roaring Fork and the Grand, southwest into the Gunnison, and east into the Arkansas. Its elevation is marked by Hayden as 13,956 feet. It is the highest pinnacle of a very irregular volcanic mass consisting of several radiating ridges one to five miles long.

The eruptive rocks of the district are marked on Hayden's Atlas of Colorado as rhyolite. They contain a large amount of uncombined silica, but sanidine is not abundant, and they more nearly resemble the quartz porphyries of Leadville than the ordinary sanidine-bearing rhyolites of central Colorado. Dark silicates occur only in small quantities locally. The volcanic mass is situated in the midst of a region of schists containing dikes and irregular bodies of granite.

The volcanic ridges have steep lateral slopes. Cliffs abound, though in many places the rock disintegrates so as to form a smooth talus of small fragments. There are a few somewhat symmetrical cones, but the general outline of the ridges is rugged, and their tops form a sierra. In several places large areas are colored bright red, and the local name for the central mass where Grizzly Peak is situated, is Red Mountain. The color is due more to the oxidation of pyrite than to the decomposition of iron-bearing silicates.

Wherever the lava is exposed on the surface, as it often is toward the tops of the ridges and on some projecting bosses and crags, it is somewhat scoriaceous and decomposed. But over most of the higher portions of the ridges the lava is capped by a layer of breccia composed mostly of fragments of the lava that are only a little polished and rounded at the angles. In some places are many subangular fragments of granite or schists lying upon or among the lava fragments, often being so abundant as to form all of the surface layer of the breccia near the top of the mountains. I saw a granite bowlder six feet in diameter embedded in a solid breccia consisting of lava fragments.

In some cases the volcanic rock extends to near the bottoms of the ridges, but in general it forms the upper half or two-thirds of the ridges. Over the lower portions of the volcanic ridges and thence extending for a short distance down the slopes over the adjacent granite and schists, we find a superficial layer of firmly cemented breccia consisting wholly of rather small fragments of schists with some granite. In several places this is shown by mining tunnels to be fifty and sometimes even more than one hundred feet thick. I found one tunnel that had penetrated the breccia into granite and schists in place, in the midst of which is a vertical dike of quartz porphyry bordered on each side by a vertical layer of breccia several feet in thickness. This was composed almost if not entirely of crushed granite and schists. In places the granitic breccia forms a terrace along the side of the mountain. I noticed one place where this breccia rests on schists that have been broken, faulted, and brecciated along the lines of fracture, so that blocks of schistose rocks twenty to sixty feet in diameter are separated by zones or vein-like bodies of schist-breccia one to four feet thick. The fragments are only a little rounded, although different kinds of schists are promiscuously mixed, showing that there was considerable faulting.

In a paper on the "Granitic Breccias of the Cripple Creek District" * I have described somewhat similar breccias to those found in the Grizzly Peak district, but on a far larger scale than the latter. However, the latter are very suggestive when we study the question of origin.

Obviously when ejectamenta were hurled by violent explosions over a large area adjacent to the volcanic vents, to form substantially horizontally-bedded breccias or conglomerates, as was the case in the San Juan mountains, Colorado, and in the Sierra Blanca range, Lincoln County, New Mexico, the fragments of the older rocks that were ejected from the vents ought to have been covered and mixed with later ejectamenta composed of volcanic rocks. But in the case of the dikes at Cripple Creek above cited, also those at Grizzly Peak, we find the fragments of older rocks overlying the fragments of volcanic rocks, and these in turn overlying rather narrow dikes that show but little lateral flow of the lava. The interpretation is plain. These dikes rose quietly and slowly through the pre-existing rocks. Before reaching the surface they became sufficiently solid at their upper extremities to be able to push fragments of the older rocks before them. In some cases the latter were at once cemented fast to the tops of the rising dikes or to the fragments of volcanic rock that were formed by the breaking up of the thin crust of solidified lava, as the dike slowly but irresistibly rose above the pre-existing surface. In such cases they were cemented fast to the rising dike before they could be washed away. In other cases, as the dikes rose above the original surface, the fragments of granite, schists, or other rocks penetrated by the dikes, remained for a time uncemented. Under the action of gravity, frost, rain-wash, etc.,

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* This Journal, vol. v, Jan., 1898.

most of these loose fragments then slid down from the tops of the rising dikes and formed a talus over the lower slopes of the dikes and thence for a short distance over the adjoining country rocks. Here they were subsequently cemented into firm breccias.

I see no possible way for explosive volcanic eruptions to preserve large masses of fragments of the older rocks free from mixture with fragments of lava, and still less to leave them overlying all other volcanic matter.

Bowlders of the so-called rhyolite of the Grizzly Peak district are found in the moraines at Twin Lakes. This proves that the volcanic eruption occurred before the glacial epoch. The position and mode of deposition of the granitic breccias prove that at the time of the eruption the Sawatch range was already deeply dissected by erosion, and that there has not been very much erosion since.

In the paper above cited I have described the gold-bearing granitic sand-rock that formed out of the granite crushed by a rising phonolite dike at the Alhambra mine, Cripple Creek district. The facts there described show that vein waters, probably waters heated by the dike which still remained in a molten condition a few feet below the solidified upper crust, decomposed the grains of crushed granite, honeycombing the sand and replacing much of the feldspar with silica and finally cementing the sand into a firm rock. The mineralized surface crust of sand-rock was in places charged with many times as much gold as is contained in any vein that has been found below in the granite or in the phonolite dike.

Any complete theory of vein deposits will have to treat of the mineralization of the superficial crusts of breccia that formed above and along the margins of rising dikes. There are numerous instances of this class of superficial ore deposits found among the granitic breccias of the Grizzly Peak region, but the subject requires more detailed treatment than is possible within the present paper.

Colorado Springs.

ART. XIX.—*The Constitution of the Ammonium Magnesium Phosphate of Analysis;* by F. A. GOOCH and MARTHA AUSTIN.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXIX.]

IN a recent paper from this laboratory* it has been shown that the presence of ammonium chloride or other ammonium salt is necessary in the precipitation of manganese as the ammonium manganese phosphate by microcosmic salt in order that the precipitate may have the ideal constitution represented by the symbol NH_4MnPO_4.

It was also shown that the solvent effect of the ammonium chloride upon the precipitated ammonium manganese phosphate is not marked when an excess of the precipitant is present in solution.

The relations disclosed in this paper suggest that the chemical constitution of the precipitate rather than mechanical contamination and varying solubility—the explanations generally accepted, and, indeed, advocated by one of us in a former paper†—may be responsible for observed variations in the weight of the residue derived by the ignition of the similar salt of magnesium, the ammonium magnesium phosphate, precipitated by an excess of a soluble phosphate from the solution of a magnesium salt, or from the solution of a soluble phosphate by an excess of a magnesium salt.

Precipitation by Excess of the Soluble Phosphate.

The precipitation of the magnesium salt by an excess of the soluble phosphate was first studied. For this work a solution of pure magnesium nitrate was prepared by dissolving the pure magnesium oxide of commerce in a slight excess of pure hydrochloric acid and boiling with more magnesium oxide. After filtering off the excess of magnesium oxide and any trace of iron or members of the higher groups, the solution was precipitated by ammonium carbonate, the precipitate was washed by repeated boilings and filtrations until silver nitrate gave no precipitate in the solution acidified with nitric acid. This precipitated carbonate was nearly dissolved in nitric acid and the solution was boiled with an excess of the carbonate (for the purpose of removing traces of barium, strontium, and calcium) filtered, and diluted to definite volume. The evaporation of a definite volume of the solution and strong ignition of the residue would be a most natural method of establishing a standard of the solution, were it not for the fact pointed out by Richards and Rogers* that the oxide of magnesium retains on ignition occluded nitrogen and oxygen enough to increase its weight sensibly. For this reason the nitrate was converted to the sulphate and weighed as such—either by evaporating to dryness in a weighed platinum crucible a definite volume of the solution, igniting as oxide, and changing to the sulphate by heating with sulphuric acid; or, by evaporating the magnesium nitrate directly with an excess of sulphuric acid of half strength. In this treatment the excess of acid was removed by heating the platinum crucible upon a porcelain ring or triangle so placed within a porcelain crucible that the bottom and walls of the inner crucible were distant about one centimeter from the bottom and walls of the outer crucible. The excess of acid is easily removed in this way, and the outer crucible may be heated to redness without danger of breaking up the magnesium sulphate. The results of this work, taking O = 16, Mg = 24·3, N = 14·03, S = 32·06, are given in the accompanying table.

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* This Journal, vi, 233.

† Am. Chem. Jour., i, 391.

TABLE I.

$MgSO_4$ obtained by converting ignited MgO into the sulphate. grm.	$MgSO_4$ obtained directly from 50^{cm^3} $Mg(NO_3)_2$. grm.	Theoretical amount of MgO in $MgSO_4$. grm.
0·5748	....	0·1924
0·5739	....	0·1923
....	0·5741	0·1922
....	0·5750	0·1925

The magnesium oxide obtained by direct ignition of the nitrate weighed on the average about 0·0010 grm. more than the oxide theoretically present in the weighed sulphate from equal portions of the solution.

Before proceeding to study possible chemical effects of ammonium chloride in determining the constitution of the ammonium magnesium phosphate, it is obviously necessary to define the extent to which the ammonium salt may exert a solvent action in presence of the precipitant. Fresenius estimated that ammonium magnesium phosphate is soluble in 15293 parts of cold water, but the method of investigation employed did not entirely preclude the possibility of counting as ammonium magnesium phosphate soluble material included and held in the original precipitate.† According to Kissel‡ the phosphate, which dissolves in a mixture of ammonia and water in the proportion of 0·0040 grams to the liter and in the proportion of 0·0110 grams to the liter in a similar mixture

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[*] Am. Chem. Jour., xvi, 567.

[†] Fresenius, 6te Aufl., p. 805.

[‡] Zeitschr. für Analyt. Chemie, viii, 173.

containing also eighteen grams of ammonium chloride, is practically insoluble in the latter mixture if an excess of magnesia mixture be added; and Heintz* showed that the effect of adding an excess of sodium phosphate in the solution is similar.

So far as appears, no quantitative experiments have been recorded in which the behavior of a mixture of ammonium chloride and magnesium salt and an insoluble phosphate in a solution only slightly ammoniacal has been tested, though as a matter of convenience the use of faintly ammoniacal solutions and faintly ammoniacal washwater is to be preferred to the mixture of strong ammonia and water [1 : 3] ordinarily employed. As a preliminary step, therefore, in the work to be described, experiments were made to find how small an amount of magnesium could be detected in solution by precipitating with microcosmic salt, either alone or in presence of ammonium chloride in faintly ammoniacal solutions. The ammonium chloride used for these tests (as well as in the similar quantitative work following) was purified by boiling with a faint excess of ammonia, filtering, digesting twelve hours with microcosmic salt, and filtering again. The results are given in Table II.

TABLE II.

Weight of MgO taken as the nitrate. grm.	$H(NH_4)NaPO_4 \cdot 4H_2O$ taken. grm.	Volume. cm^3	NH_4Cl taken grm.	Opalescent precipitation.
0·0003	1·75	100	--	marked
0·0003	"	500	--	"
0·0003	"	100	10	"
0·0003	"	500	10	"
0·0003	"	500	30	faint
0·0001	"	100	--	marked
0·0001	"	100	10	"
0·0001	"	500	10	faint
0·0001	"	500	60	"

The results of these tests show that even so little as 0·0001 grm. of magnesium oxide may be detected in five hundred cubic centimeters of faintly ammoniacal water containing as much as sixty grams of ammonium chloride.† It is plain that strongly ammoniacal liquids are entirely unnecessary in the precipitation of the ammonium magnesium phosphate under the conditions. In nearly all the experiments to be detailed use was made, therefore, of faintly ammoniacal solutions and wash-water.

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* Zeitschr. für Analyt. Chemie, ix, 16.

† It was found also, incidentally, that the presence of reasonable amounts of ammonium oxalate (100 cm^3 of the saturated solution) does not interfere with the precipitation of the ammonium magnesium phosphate by microcosmic salt.

In Table III are given the results obtained in a study of the effects of varying proportions of ammonium chloride and the soluble phosphate upon the constitution of the precipitate. All precipitates were gathered upon asbestos in the filtering crucible, washed in faintly ammoniacal water, and ignited as usual. In every case the precipitation was practically complete; for, upon allowing the filtrates with the wash-water to stand for several days after further addition of microcosmic salt, nothing but insignificant traces of a precipitate—not exceeding 0·0001 grm.— ever appeared. In the experiments of section A precipitations were made in the cold by the action of microcosmic salt in considerable excess upon the solutions of magnesium nitrate containing varying amounts of ammonium chloride. In experiments (1) to (5) the liquid was made faintly ammoniacal after the addition of the precipitant and the precipitate was filtered off immediately after complete subsidence; in experiments (6) to (10) the precipitate first thrown down was redissolved in a very little hydrochloric acid and reprecipitated by dilute ammonia (the operation being repeated several times) with a view to improving the crystalline condition of the precipitate, and this treatment introduced, of course, a small amount of ammonium chloride, probably less than a gram. It will be observed that errors of excess appear in all of these determinations, those being the greatest in the experiments in which the largest amounts of the ammonium salt were present.

In the experiments of section B the manipulation was so changed that the supernatant liquid was poured off (through the filtering crucible which was to be used subsequently to collect the phosphate) after the precipitate had subsided and the insoluble phosphate was dissolved in hydrochloric acid and brought down again, after dilution, by the addition of a faint excess of dilute ammonia. By thus removing the supernatant liquid after the first precipitation, the excess of the precipitant and the amounts of ammonium chloride originally present were reduced to relatively low limits, so that their effects in the reprecipitation were at a minimum; and by adding varying amounts of ammonium chloride, or none at all, before the reprecipitation, it became possible to demonstrate the individual effect of that reagent apart from that of an excess of the microcosmic salt. It will be noted that in experiments (11) and (12), in which no ammonium salt was added after the decantation from the first precipitate, the results are ideal, and that the errors of excess advance as the amounts of ammonium salt present in the final precipitation increase. The quantity of the ammonium salt present during the first precipitation does not influence the error in the final precipitation unless it is so large that a simple decantation of the supernatant liquid would naturally leave an appreciable amount of it to act when the second precipitation takes place.

TABLE III.

	$Mg_2P_2O_7$ corresponding to $Mg(NO_3)_2$ taken. grm.	$Mg_2P_2O_7$ found. grm.	Error in terms of $Mg_2P_2O_7$. grm.	Error in terms of MgO. grm.	NH_4Cl present. grm.	$HNaNH_4PO_4.4H_2O$ used. grm.	Volume. cm³.
			A				
(1)	0·5311	0·5418	+0·0107	+0·0038	—	2·5	150
(2)	0·5311	0·5462	+0·0151	+0·0057	2	"	150
(3)	0·5311	0·5408	+0·0097	+0·0035	2	"	150
(4)	0·5311	0·5500	+0·0189	+0·0068	60	"	250
(5)	0·5311	0·5520	+0·0209	+0·0075	60	"	250
(6)	0·5311	0·5345	+0·0034	+0·0012	*	"	150
(7)	0·5311	0·5371	+0·0060	+0·0022	*	"	150
(8)	0·5311	0·5384	+0·0073	+0·0026	*	"	150
(9)	0·5311	0·5386	+0·0075	+0·0027	*	"	150
(10)	0·5311	0·5415	+0·0104	+0·0037	*	"	150
			B				
(11)	0·5311	0·5312	+0·0001	+0·0000	*—	"	150,100
(12)	0·5311	0·5311	+0·0000	+0·0000	*—	"	150,100
(13)	0·5311	0·5346	+0·0035	+0·0013	2+2	"	150,100
(14)	0·5311	0·5348	+0·0037	+0·0014	2+2	"	150,100
(15)	0·5311	0·5383	+0·0072	+0·0026	5+5	"	150,100
(16)	0·5311	0·5368	+0·0057	+0·0021	5+5	"	150,100
(17)	0·5311	0·5376	+0·0065	+0·0023	10+10	"	200,100
(18)	0·5311	0·5395	+0·0084	+0·0030	10+10	"	200,100
(19)	0·5311	0·5396	+0·0085	+0·0031	60+5	"	250,100
(20)	0·5311	0·5389	+0·0078	+0·0028	60+5	"	250,100

It is plain that the errors of excess which appear when either the ammonium chloride or the soluble phosphate is present in considerable amount, must be due either to mechanical inclusion on the part of the highly crystalline precipitate, or to variation in the ammonium magnesium phosphate from the ideal constitution toward a condition represented by a phosphate richer in ammonia and correspondingly deficient in magnesium. If any appreciable amount of the ammonium chloride present were held by the precipitate, it would naturally be represented by magnesium chloride after ignition, but, in no one of these experiments, even in those dealing with sixty grams of ammonium chloride, did the residue, after dissolving in nitric acid, give with silver nitrate evidence of the presence of more than a mere unweighable trace of chloride. A special experiment, moreover, in which an attempt was

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* Probably less than 1 grm

made to determine the silver chloride precipitated from the solution in nitric acid of an unignited precipitate thrown down by microcosmic salt in presence of sixty grams of ammonium chloride, confirms this conclusion: the precipitate was unweighable. If ammonium chloride present in the solution to so great an amount is not included in the precipitate in significant quantity, it would seem to be unnatural that the microcosmic salt should be included mechanically in any very great amount. But unless the microcosmic salt was mechanically included, the increase in weight must be due to the chemical influence of the reagents—that is, to the production of a phosphate rich in ammonium and deficient in magnesium. Berzelius* recognized the existence of such a phosphate of magnesium; but Wach,† in following the work of Berzelius, failed to find it. No attention seems to have been given since to the existence of such a salt. It would be natural to expect its formation, if ever, when the precipitating phosphate is in excess and ammonium salts are present in abundance, with free ammonia. Obviously the natural effects of all these reagents would be toward the production of a salt holding more ammonia and more phosphoric pentoxide for a given amount of magnesium. The results of the table seem to point strongly to such tendencies, and, by inference, toward the existence of such a compound. Thus in experiments (11) and (12), in which the greater part of this excess of microcosmic salt was removed by decantation before the second precipitation, while no ammonium chloride was present excepting the small amount made by the solution and reprecipitation of the first precipitate, the error is practically nothing. In experiments (13) and (14), (15) and (16), (17) and (18), all similar to (11) and (12) excepting that ammonium chloride was present, the average errors— +0·0036 grm. in terms of magnesium phosphate, 0·0064 grm., +0·0074, respectively—increase as the ammonium chloride is increased in the final precipitation. In experiments (19) and (20), in which the ammonium chloride amounted to sixty grams in the first precipitation and to five grams in the second in addition to the amount that would naturally remain after decanting the strong solution of the former precipitation, the similarity of this error (+0·0082 in the mean) to that of the experiments in which smaller amounts of the ammonium chloride were used throughout goes to show that only the amount of ammonium salt present in the final precipitation counts. Further, a comparison of corresponding experiments of A and B shows very plainly that the treatment which involves the removal of the large part of the microcosmic salt, the solution of the precipitate, and reprecipitation tends to reduce the higher indications. Thus, for example, the error in (2) and (3) is +0·0124 grams in terms of magnesium pyrophosphate, while in (13) and (14), similarly carried out except the decantation of the excess of the precipitant, solution and reprecipitation, the error is +0·0036 grm.

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* Berzelius, Jahresbericht 3 Jahrgang (1824) übersetzt von C. G. Gmelin s. 92.

† Schweigger, 1830, Band 29, s. 265.

The special influence of free ammonia during precipitation, was investigated in the following experiments. Definite volumes of the magnesium nitrate solution were drawn from a burette into a platinum dish, ammonium chloride—10 grm.—was added, the magnesium was brought down by dilute ammonia in presence of microcosmic salt, and strong ammonia equal to one-third the volume of the solution was added. The solutions, after standing, were filtered off on asbestos under pressure in a perforated crucible, and the precipitates were washed with ammonia diluted to the proportion of three parts of water to one of ammonia, dried after moistening with a drop of saturated solution of ammonium nitrate, ignited and weighed. The results are given in experiments (1) and (2) of Table IV. In these determinations the mean error reaches +0·0183 grm. in terms of magnesium pyrophosphate; while in experiments (3) and (4), made similarly excepting that the supernatant liquid was decanted from the precipitate first thrown down, the precipitate dissolved in hydrochloric acid, and after dilution reprecipitated by dilute ammonia immediately supplemented by enough strong ammonia to make one-fourth the volume of the entire solution, the error amounts in the mean to +0·0061 in terms of the pyrophosphate.

TABLE IV.

	$Mg_2P_2O_7$ corresponding to $Mg(NO_3)_2$ taken. grm.	$Mg_2P_2O_7$ found. grm.	Error in terms of $Mg_2P_2O_7$. grm.	Error in terms of MgO. grm.	NH_4Cl present. grm.	$HNaNH_4PO_4 . 4H_2O$ used. grm.	Volume. cm³.
(1)	0·5311	0·5503	+0·0192	+0·0069	10	2·5	200
(2)	0·5311	0·5505	+0·0194	+0·0070	10	2·5	200
(3)	0·5311	0·5393	+0·0082	+0·0029	10, —	2·5	200,100
(4)	0·5311	0·5351	+0·0040	+0·0017	10, —	2·5	200,100

In experiments (1) and (2) the precipitate was influenced by an excess of microcosmic salt, ammonium chloride, and free ammonia in large amount; in experiments (3) and (4), by decanting in the manner previously described, by dissolving the precipitate, and reprecipitating, the effects of an excess of microcosmic salt and ammonium chloride are reduced to a minimum, and, in a comparison of the results with those of experiments (11) and (12) of Table III the tendency of the free ammonia comes to view. The results discussed seem certainly to point to a general tendency on the part of free ammonia, ammonium chloride and excess of the phosphate to produce a salt rich in ammonia and deficient in magnesium, which for a definite amount of magnesia precipitated must leave upon ignition a residue weighing more than the normal phosphate.

If it be assumed that a salt of the symbol $(NH_4)_4Mg(PO_4)_2$— the next natural step to the normal salt, NH_4MgPO_4—is present in the precipitate, the residue which such a salt would leave upon ignition would be the metaphosphate $Mg(PO_3)_2$. From the relations of the symbols for magnesium pyrophosphate and magnesium metaphosphate the weight of the residue obtained, and the weight of the pyrophosphate theoretically derivable from the weight of magnesium salt used, it is possible, of course, to calculate the proportionate amounts of pyrophosphate and metaphosphate present in any ignited residue. Proceeding in this manner, it appears, that, in order to account for the variations noted, it is necessary to assume the presence in many cases of very considerable amounts of the metaphosphate. Thus, in the case of those results obtained according to the usually accepted method of precipitating and washing with strongly ammoniacal liquids, viz. in experiments (1) and (2) of Table IV, the proportion of metaphosphate needed to account for the observed error reaches ten per cent.

Precipitation by Excess of the Magnesium Salt.

The relations which obtain in the reverse process of precipitation—the action of an excess of the magnesium salt upon a soluble phosphate—were studied in experiments to be described. A solution of pure hydrogen disodium phosphate was prepared by carefully recrystallizing the pure salt of commerce five times from distilled water in a platinum dish, dissolving the crystals, and diluting to definite volume. The standard of the solution was established by evaporating to dryness in a weighed platinum crucible known volumes of the solution, igniting the residue and weighing the sodium pyrophosphate. Magnesia mixture, the precipitant, was prepared by dissolving fifty-five grams of magnesium chloride in as little water as possible and filtering, mixing with this solution twenty-eight grams of ammonium chloride purified by treating it in strong solution with bromine water and a slight excess of ammonia, filtering, diluting to one liter, and, after standing for some hours, filtering again.

The tests of the following table show that the precipitation of a soluble phosphate by the magnesia mixture is practically complete in faintly ammoniacal solutions even when very dilute and charged with large amounts of ammonium chloride, provided the magnesia mixture is present in sufficiently large excess.

TABLE V.

P_2O_5 in HNa_2PO_4 taken. grm.	Magnesia mixture. cm³.	Volume. cm³.	NH_4Cl. grm.	Precipitation.
0·0005	10	100	..	Visible at once
0·0005	50	100	..	throughout the liquid.
0·0005	10	100	10	"
0·0005	10	200	60	"
0·0001	50	250	60	"
0·0001	10	100	..	"
0·0001	10	100	10	"
0·0001	50	200	10	"
0·0001	10	250	60	"
0·0001	50	300	60	Visible after
0·0001	50	500	60	settling out.

This conclusion was further substantiated by an actual test (by the molybdate method) of the ignited residue, obtained by evaporating a filtrate from ammonium magnesium phosphate (equivalent to 0·8614 grams of the pyrophosphate) precipitated by a faintly ammoniacal solution of magnesia mixture in presence of sixty grams of ammonium chloride, which gave a precipitate of ammonium phosphomolybdate yielding 0·0002 grams of magnesium pyrophosphate. It is evident, therefore, that any considerable deficiencies of weight of the magnesium phosphate obtained by precipitating equal amounts of a soluble phosphate by magnesia mixture in presence of varying amounts of ammonium chloride, cannot be attributed to varying solubility of the magnesium phosphate under changing proportions of the ammonium chloride.

The results recorded in section A of Table VI were obtained by treating definite volumes of the pure solution of hydrogen disodium phosphate with magnesia mixture, in slight excess above the amount required to bring down the phosphate, and making the solution distinctly ammoniacal. After thorough subsidence, the precipitate was filtered off on asbestos under pressure in a perforated platinum crucible, washed in water faintly ammoniacal, dried, ignited and weighed. In experiments (1), (5) and (6), only the ammonium chloride present in the magnesia mixture was used; in the other cases weighed portions were added. In the experiments of section B, the precipitate was dissolved in hydrochloric acid after filtering off the supernatant liquid, brought down again in dilute solution by ammonia in distinct excess, and thereafter treated as in the experiments of section A. The experiments of section C were conducted similarly to (1), (5) and (6) of A excepting that the magnesium mixture was introduced into the ammoniacal solution of the phosphate drop by drop from a burette. The precipitations in A, B and C were proved to be practically complete; for by treatment of the filtrates with more magnesia mixture and standing, no more than a trace—0·0001 grm. at the most—of the phosphate was found. The ignited residues never contained more than a mere trace of chlorine.

TABLE VI.

	$Mg_2P_2O_7$ corresponding to HNa_2PO_4 taken.	$Mg_2P_2O_7$ found.	Error in terms of $Mg_2P_2O_7$	Error in terms of P.	Volume.	NH_4Cl in magnesia mixture.	NH_4Cl added.	$MgCl_2$. $6H_2O$ in magnesia mixture.
	grm.	grm.	grm.	grm.	cm^3.	grm.	grm.	grm.
				A				
(1)	0·8615	0·8613	—0·0002	—0·00005	150	1·68	....	3 3
(2)	0·8615	0·8615	0·0000	0·00000	200	"	20	"
(3)	0·8615	0·8602	—0·0013	—0·00036	200	"	20	"
(4)	0·8615	0·8561	—0·0054	—0·00151	300	"	60	"
(5)	0·0852	0·0862	+0·0010	+0·00028	100	0·28	....	0·55
(6)	0·0852	0·0866	+0·0014	+0·00039	100	"	....	"
(7)	0·0852	0·0847	—0·0005	—0·00014	200	"	20	"
(8)	0·0852	0·0830	—0·0022	—0·00062	200	"	20	"
(9)	0·0852	0·0811	—0·0041	—0·00115	300	"	60	"
				B				
(10)	0·8111	0·8114	+0·0003	+0·00008	150,100	1·68	..,..	3·3
(11)	0·8615	0·8613	—0·0002	—0·00006	150,100	"	..,..	"
(12)	0·8615	0·8578	—0·0037	—0·00103	200,100	"	..,20	"
(13)	0·8615	0·8487	—0·0128	—0·00358	200,100	"	..,60	"
(14)	0·0852	0·0857	+0·0003	+0·00008	100,100	0·28	..,..	0·55
(15)	0·0852	0·0656	+0·0004	+0·00011	100,100	"	10,..	"
(16)	0·0852	0·0853	+0·0001	+0·00003	150,100	"	10,10	"
(17)	0·0852	0·0819	—0·0033	—0·00092	200,100	"	20,20	
				C				
(18)	0·8111	0·8071	—0·0040	—0·00112	120	1·4	....	2·75
(19)	0·8111	0·8052	—0·0059	—0·00165	120	1·4	....	2·75

While the results are not entirely regular, the tendency of the ammonium salt to produce errors of deficiency in proportion to its amount is plain if we compare among themselves the experiments of A upon similar amounts of phosphate, and then those of B upon similar amounts of phosphate among themselves; and by a comparison of corresponding results in A and B it is clearly shown that the presence of an excess of magnesia mixture tends to counteract more or less completely errors of deficiency due to the action of the ammonium chloride. These facts are quite in harmony with the hypothesis that the ammonium salt tends to produce an ammonium magnesium phosphate richer in ammonia and phosphoric acid and poorer in magnesia than the normal salt NH_4MgPO_4; for, though the production of such a salt in presence of an excess of the soluble phosphate compels the combination of a definite amount of magnesium with more than the normal amounts of phosphoric acid and ammonia (as was the case in the former series of experiments), when the supply of the soluble phosphate is limited the amount of magnesium associated with it must fall below the normal (as is the case in the present series of experiments). Moreover, the behavior of the precipitant is quite in accord with the hypothesis; for, though the influence of an excess of the soluble phosphate would naturally tend (as was observed) in the same direction as that of the ammonium salt and free ammonia, viz., to the production of the phosphate deficient in magnesium, the tendency of an excess of the magnesium salt must obviously be to increase the amount of magnesium in the phosphate, as was observed in the experiments of Table VI. The hypothesis fits the facts, therefore, on both sides; and, if precipitation is practically complete (as was shown to be the case throughout) the argument for the existence of an ammonium magnesium phosphate—poorer than the normal salt in magnesium—possibly the salt $(NH_4)_4Mg(PO_4)_2$ —seems to be strong.

The Practical Determination of Magnesium and Phosphoric Acid.

In determining magnesium by the procedure in ordinary use, the tendency is strong—as is shown in experiments (1) and (2) of Table IV—toward high plus errors, and the error is due to the combined effects of excesses of the precipitant, the ammonium salt, and free ammonia. The experiments (11) and (12) of B, Table III, show conclusively that such tendencies to error may be counteracted effectively by pouring off the supernatant liquid (through the filter to be used subsequently to collect the precipitate) as soon as the precipitate subsides, dissolving the phosphate in the least amount of hydrochloric acid, bringing it down again, after dilution, by a faint excess of ammonia, filtering (best, we think, on asbestos, under pressure), washing with faintly ammoniacal water, and igniting as usual.

Many years ago* a method of precipitating the ammonium magnesium phosphate was advocated by Professor Wolcott Gibbs, which consists, essentially, in boiling the solution of the magnesium salt with microcosmic salt and adding ammonia after cooling, and by which most exact analytical results were obtained. Our experience confirms completely that of Dr. Gibbs, and we desire to direct attention again to a procedure the advantage of which has, unfortunately, not been broadly known and accepted. Even in the presence of considerable amounts of ammonium chloride this process yields a phosphate of nearly ideal constitution if only the boiling be prolonged from three to five minutes. The greater part of the ammonium magnesium phosphate—about 90 per cent—forms in this process before free ammonia is added, and the ammonium which enters the phosphate thus formed is derived from the microcosmic salt, which must become correspondingly acidic. Under these conditions, the tendency to form an insoluble ammonium magnesium phosphate richer in ammonia and poorer in magnesia than the normal salt, does not develop. In the process of Dr. Gibbs, as well in the modified precipitation process in the cold, the use of the faintly ammoniacal solution and wash-water is sufficient and advantageous.

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* This Journal [3], v, 114.

In the precipitation of a soluble phosphate by magnesia mixture the tendency of the precipitant and that of the ammonium salt are antagonistic, so that the effect of the latter salt is somewhat masked, though manifest. This opposition of effects has been noted by Mahon,* who, though regarding the actual attainment of an exact balance as uncertain, ventures the opinion that accurate results should be attainable by the careful relative adjustment of the proportions of the precipitant and ammonium salt. Mahon claims to get the best results by a very gradual addition of magnesia mixture to the ammoniacal solution of the phosphate containing about sixteen per cent of ammonium chloride, strong ammonia being added subsequently. From our observations, however, recorded in section C of Table VI, it appears that the method of introducing the magnesia mixture gradually into the ammoniacal phosphate (taken in quantity sufficiently large to give unmistakable indications) produces a precipitate deficient in magnesium and so leads to errors of deficiency in the phosphorus indicated. The use of strong ammonia, moreover, we have shown to be both unnecessary and disadvantageous. Our experiments go to show that good results may be expected when the solution of the phosphate containing a moderate excess of the magnesium salt and not more than five to ten per cent of ammonium chloride is precipitated by making it slightly ammoniacal, the precipitate being washed in slightly ammoniacal wash-water. In general, however, and especially when more ammonium chloride than this proportion, or more magnesium salt than twice the amount theoretically necessary, is present, it is safer to decant the supernatant liquid from the precipitate (through the filter to be used subsequently to hold the phosphate), to dissolve the precipitate in a little hydrochloric acid and reprecipitate by dilute ammonia, washing with faintly ammoniacal wash-water.

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* Jour. Amer. Chem. Soc., xx, 445.

ART. XX.—*The Crystal Symmetry of the Minerals of the Mica Group;* by T. L. WALKER, Assistant Superintendent Geological Survey of India.

FROM the time that the symmetry of crystals was determined exclusively by the aid of goniometrical measurements, there has been a constant degradation of crystals from systems of higher symmetry to those of lower symmetry. Many substances which were once regarded as tetragonal are now looked upon as rhombic; others that were supposed to be rhombic have been shown to be monoclinic, while monoclinic has frequently given way to triclinic. The movement has always been downward, lower symmetry replacing higher. This has been due in a small measure, to the improvement that has been made in goniometers, but principally to the progress of physical investigation of minerals. At first it was considered remarkable that the optical properties of cubic crystals should be strikingly different from those of tetragonal and hexagonal crystals, which in turn differed widely optically from rhombic, monoclinic and triclinic crystals. At the present time, however, physical crystallography is looked upon as so important that no crystal can be admitted to any crystal system till it has been examined as to its optical, thermal, electric and cohesive, as well as to its geometrical properties. Only when the physical and morphological properties agree in every respect, is it safe to assign a crystal to a particular system.

The degradation caused by placing physical and morphological examination of crystals on equal footing, found its climax in the writings of Mallard,* who seems to have concluded that all crystals are composed of asymmetric particles which may by twinning simulate higher grades of symmetry—sometimes we can detect this twinning geometrically or physically, but even when we cannot detect it, we are to suppose it to exist on a scale so fine that our means of examination are insufficient.

The study of etching figures as an indicator of crystal symmetry, is one of the newest means discovered by the physical crystallographer. This method is often so much more delicate than even the optical method that it points to wholesale degradation. Not only is it much more delicate than the optical method, but it can often be used when no conclusion can be obtained by any other means. There have been many protests against admitting the evidence of this latest and most radical witness, as is exemplified by Brauns, when he says: " *Würde*

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* E. Mallard, Explication des phénomènes optiques anomaux, Paris, 1877.

man in dieser Weise die Form der Aetzfiguren unter allen Umständen als ausschlagend ansehen, so würde es bald dahin kommen, dass man nur noch asymmetrische Krystalle kennt."* It may be urged, however, that etching figures are always in agreement with the optical properties, and, so far as we can test them by other reliable methods, they are found to be in agreement.

Few minerals better show this tendency to degradation from higher to lower symmetry than do the minerals of the mica group. The difficulty in determining the crystal system of the micas by goniometrical measurements is seen in the way in which very eminent minerologists have differed: Marignac and Kenngott held that some micas were hexagonal, and others monoclinic. Senarmont considered them all as rhombic; the late J. D. Dana at one time looked upon them as partly hexagonal and partly rhombic; Leydolt found the etching figures on muscovite cleavage plates to be symmetrical about only one line, and concluded that the micas were rhombic, but hemimorphic about the brachydiagonal. In 1875 Tschermak observed that the optical axis is not exactly at right angles to the basal cleavage and concluded that the micas were monoclinic. The only further degradation possible for the minerals of this group was suggested by Wiik,† who observed that the etching figures on basal cleavage plates are often asymmetric and concluded that at least part of the micas were triclinic. These results of Wiik, though well known, have not led mineralogists to look on the micas as triclinic: at present all text-books describe the micas as monoclinic. The object in writing this paper is to emphasize the conclusions of Wiik by giving additional evidence in favor of regarding some, at least, of the micas as triclinic.

We are accustomed to speak of two classes of micas: 1st, those whose optical plane is parallel to the clinopinacoid, and 2nd, those whose optical plane is at right angles to the clinopinacoid. As the six-rayed percussion figure has one ray parallel to the clinopinacoid, we may determine the crystallographic orientation of crystal fragments by selecting that ray as clinopinacoidal which is either parallel to or at right angles to the optical plane. While examining a specimen of rubellan from the Eifel in this way to determine its orientation, it was observed that the optical plane was neither at right angles nor parallel to any ray of the percussion figure but inclined to one of the rays at an angle of about seven degrees. This led to wider examination of micas and to the following results.

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* R. Brauns, Die optische Anomalien der Krystalle, Leipzig, 1891.

† Öfvers. Finska Vet. Soc. Förh. 1880.

Phlogopites.

The measurements were made on the stage of an ordinary petrological microscope and may be considered accurate to degrees but not to fractions of a degree. The majority of the specimens examined were cleavage sheets, either without crystal edges or with edges which were too rough for exact measurement. All those with sharp crystal edges showed that the edge 001 $\wedge$ 010 is parallel to one of the rays of the percussion figures, so that, where good edges were absent the divergence of the optical plane from the commonly accepted position was measured against that ray of the percussion figure which was nearest to being parallel to it. The divergence for any one specimen varied with different sheets and for different parts of the same sheet. Cleavage fragments about half a millimeter thick often showed no divergence whatever, but when split to, say a fourth of that thickness, very considerable divergence was noted, some thin cleavage fragments from one and the same crystal showing very much more than others of the same thickness. This, though apparently true in most cases, is particularly plain in the case of small amber-colored transparent crystals from crystalline limestone from Upper Burma, which at a thickness of 1^{mm} generally show no divergence, but thin plates, about a tenth of that thickness, show a maximum divergence of 11° 30′. The position of the optical plane on one of these Burmese crystals is shown in fig. 1, p. 204. The maximum observed divergences on phlogopites are shown below.

Locality.	Maximum observed. Divergence.	Angle χ*.	Material used.
Canada.			
Templeton, P. Q.	9°	----	Cleavage fragments.
South Burgess, Ont.	13	61° 53′	" "
United States.			
Winchester, Pa.	17	----	" "
De Kalb, St. Lawrence Co., N. Y.	6 20′	61 30	" "
Pierrepont, " "	4 20	----	" "
Rossie, " "	2 30	60 50	" "
Macomb. " "	3 30	63 30	" "
Hammond, " "	10 30	----	Crystals.
Pope's Mill, Jefferson Co., N. Y.	7 30	63	Cleavage fragments.
Muscalonge Lake, N. Y.	8 30	----	Crystals.
Finland.			
Pargas	14°	----	"
------	8	----	"
India.			
Upper Burma	11° 30′	60° 20′	"
Travancore	14	63 14	Cleavage fragments.
Merzapur	3	59 20	" "
Ceylon.			
Radigara	13°	63° 28′	" "
------	15	62 27	" "

*The angle of the percussion figure opposite the clinopinacoidal edge.—Vide this Journal, ii, 5, 1896.

These observations prove that in phlogopite the optical plane is neither parallel to nor at right angles to the clinopinacoid (so called) and compels us to regard this mineral as triclinic, which agrees with the conclusions of Wiik, founded upon the asymmetric etching figures on the basal cleavage plates, as shown in fig. 2 [after Wiik]. The fact that thicker cleavage plates often give no divergence accounts for the common view as to the position of the optical plane being parallel to the clinopinacoid. The freedom from divergence in the thicker plates is to be accounted for by supposing the mica to be twinned polysynthetically in very thin lamellae with (001) as composition face, which is the commonest recognised twinning law for micas, the apparent optical plane in a thick crystal plate representing the average for the different crystal individuals which go to form the cleavage plate. The maximum divergence then becomes the divergence for a sheet which consists of a single individual; those peculiar etching figures, which are somewhat hexagonal in outline with two small inscribed equilateral triangles with their points so arranged as to constitute a six-pointed star, would also be explained on the supposition that one of the triangles represents the etching figures for one very thin individual, and the other triangle the figures for the individual immediately below.

Biotite.

It is difficult to determine the *exact* position of the optical plane in the biotites, for the optical angle is so small that the hyperbolas of the interference figure scarcely separate when rotated between crossed nicols in convergent polarised light. This difficulty is also increased by the much darker color of the biotites and by their giving much poorer percussion figures against which to measure the divergence in the absence of crystal edges on the plates. A few of the many biotites examined gave definite results.

Locality.	Divergence.	Material used.
India.		
Hazaribagh, Bengal	9°	Cleavage fragments of biotite.
Siberia.		
Lake Baikal	5	" " "
Sweden.		
Wermland.........	9° 30′	Cleavage fragments of lepidomelane.
Prussia.		
Eifel	7	Crystal of rubellan.

These observed divergences would refer biotite to the triclinic system which agrees with the etching figures obtained by Wiik reproduced in fig. 3.

Lithia Micas.

Only about half a dozen specimens of lepidolite and zinnwaldite were available for examination. The optical plane is sometimes parallel to, at other times at right angles to, one of the rays of the percussion figure, but never divergent as in the case of biotite and phlogopite. This is all the more remarkable, for the etching figures obtained by both Baumhauer and Wiik are so very plainly triclinic in symmetry. Wiik's figures are reproduced in figs. 4 and 5.

Muscovite.

The optical examination shows no evidence for suspecting that this mica is other than monoclinic, as we at present regard it—this agrees with the etching figures of Leydolt, Baumhauer and Wiik. The optical plane is always at right angles to one of the rays of the percussion figure, as is consistent with monoclinic symmetry. Wiik's etching figures are represented in fig. 6.

From the above statement it seems evident that part of the micas are triclinic—biotite, phlogopite, rubellan, lepidomelane lepidolite, and zinnwaldite, while muscovite is either monoclinic, or, if it be triclinic, it is very finely polysynthetically twinned that we cannot find a triclinic individual large enough to respond to the optical or etching method. According to Mallard, these two are the same—monoclinic crystals (so called) are merely very finely intergrown triclinic twins, the symmetry plane of the monoclinic being due to the increase of symmetry which always accompanies twinning. Lévy has suggested that orthoclase or monoclinic potash feldspar is merely a very finely twinned microcline. A similar relation may hold for the micas.

Some observers have referred to the etching figures on the micas as of monoclinic symmetry. The form of the figures depends on the reagent used, its strength and the duration of the action. Though the physical symmetry of the crystals acted upon is always the same, there may be different amounts of symmetry revealed by different conditions, just as alum may be grown in forms which are geometrically holohedral, as is the case if the crystals are formed in neutral or alkaline saturated solutions, but if grown from hydrochloric acid solutions, pyritohedral faces are nearly always present, affirming that all alum crystals are physically hemihedral even when geometrically holohedral. It would be as unsafe to maintain that the micas are monoclinic, because under some conditions certain reagents give etching figures which *appear* to be monoclinic in symmetry, as it would be to conclude that all alum crystals are physically holohedral because under certain conditions crystals of alum may be obtained which are morphologically holohedral.

I have to thank Professors F. W. Clarke, Washington, D.C., S. L. Penfield, New Haven, Ct., G. Tschermak, Vienna, F. J. Wiik, Helsingfors, and A. Lacroix, Paris, for their kindness in sending me specimens of phlogopites.

Indian Museum, Calcutta, July, 1898.

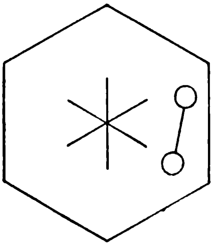

Fig. 1

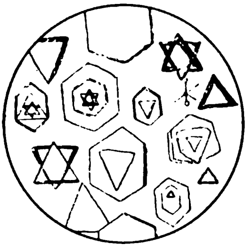

Fig. 2

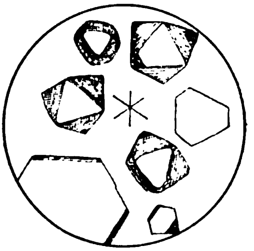

Fig. 3

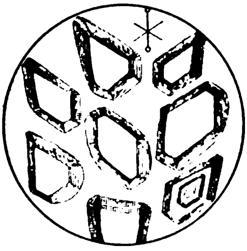

Fig. 4

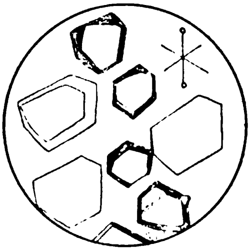

Fig. 5

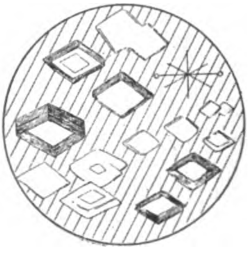

Fig. 6

EXPLANATION OF FIGURES.

Figure 1.—Cleavage plate from a crystal from Upper Burma, showing the positions of the percussion figure and optical plane.

Figure 2.—Etching figures on phlogopite from Pargas, obtained by hydrofluoric acid. [After Wiik.]*

Figure 3.—Etching figures on biotite obtained by hydrofluoric acid. [After Wiik.]*

Figure 4.—Etching figures on zinnwaldite, showing twinning, obtained by hydrofluoric acid. [After Wiik.]*

Figure 5.—Etching figures on rose-red lepidolite from Mursinsk, obtained by action of hydrofluoric acid. [After Wiik.]*

Figure 6.—Etching figures on muscovite from Kimito, obtained by action of hydrofluoric acid. [After Wiik.]*

*loc. cit.

ART. XXI.—*Descriptions of imperfectly known and new Actinians, with critical notes on other species*, IV; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College*, No. LXI.

Family PARACTIDÆ. (Continued from p. 146.)

Raphactis Caribœa, sp. nov. Figures 17, A, B, page 146.

Base amplexicaul, surrounding completely the branch of a gorgonian, the two lobes united beneath by suture. The axial line of the stomodæum lies across the branch, in the type. Column low, its surface covered by slightly raised elevations, due apparently to wrinkles, their surfaces smooth; a few small warts are scattered near the collar, which is thickened and has about 30 small, short, crowded, longitudinal ridges; their lower or outer end is largest and most raised. Tentacles numerous, about 72, crowded in four or five rows, moderately stout, tapered, entirely retractile. Mesenteries numerous, thin, about 36 pairs join the outer part of the disk, where some of the smallest bear small gonads. About 12 pairs join the upper part of the stomodæum, but lower down there appear to be only six perfect pairs, most of which are fertile, if not all. Their longitudinal muscles are broad and very thin.

Height of column of contracted specimen, 4^{mm}; longest diameter 11^{mm}. Color unknown.

Off St. Vincent, W. Indies, 124 fath., Blake Exped., on a brown gorgonian.

Stomphia Gosse, 1859.

Carlgren, op. cit., p. 86, 1893.

This genus, established for *S. Churchiæ* alone,* has been studied anatomically and histologically by Carlgren. It is very nearly allied to what I consider typical *Paractis*.† It has a smooth wall, much thickened at the submarginal fold. There are 16 to 24 pairs of perfect mesenteries, the number being variable; their longitudinal muscles are thin and diffuse. The perfect and part of the imperfect mesenteries are gonophoric, in the type. Tentacles are numerous and rather stout.

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* *Paractis vinosa* McMur., op. cit., 1894, p. 167. appears to be related to *Stomphia*. The number of tentacles is said to be 64, but "the mesenteries are 32 in number, 16 being perfect" (p. 164), and "only the imperfect mesenteries are gonophoric." The number of tentacles given would indicate the presence of 32 *pairs* of mesenteries, which Prof. McMurrich informs me is the case, an error having occurred in his description. The agreement with *Stomphia* is therefore close, except that in our larger examples of the latter the perfect mesenteries are also gonophoric.

Cymbactis fæculenta McMur., op. cit., 1893, p. 174, seems also related rather closely to *Stomphia*, but has thicker mesoglœa, fewer tentacles, 12 pairs of perfect mesenteries, and a feebler sphincter than the type.

† I do not consider *Paractis excavata* Hert. a true *Paractis*. The latter name should be restricted to such plain forms as agree externally with *P. impatiens* (Dana). The latter is the first species named by Edw. and Haime and should be the type if it prove, when anatomically studied, to be a paractid. If not, then some of the other named species of similar form should be taken as the type. *P. nivea*, described below, is such a species, but cannot be taken as the type, for it

Stomphia carneola (Stimp.) Ver. Figures 24, 24*a*–24*d*.

Actinia carneola Stimpson, Invert. Grand Manan, p. 7, 1852.

Rhodactinia Davisii (var. 4) Verrill, Revision Polyps E. coast U. States, pp. 19, 20, 1864.

? *Stomphia Churchiæ* Gosse, Ann. Nat. Hist., Ser. III, vol. iii, p. 48, 1859; Actinol. Brit., p. 222, pl. viii, fig. 5, 1860. Andres, op. cit., p. 369. 1884.

Carlgren, Kongl. Svenska, Vet.-Akad. Handl., xxv, 2, p. 80, pl. i, viii, ix, x (anatomy and histol.), 1892.

? *Stomphia coccinea* (Müll.) Carlgren, op. cit., appendix, p. 138 (not *Sagartia coccinea* Gosse, perhaps not Müller's sp.)

Column and base very versatile in form; the base may be broadly expanded or much contracted; and when detached may become small and puckered or swollen and conical. Column may be cylindrical, or almost hour-glass-shaped, or bottle-shaped, these changes taking place very rapidly. The wall is smooth in expansion, more or less wrinkled when contracted; there are neither verrucæ nor suckers; a distinct thickened marginal fold or collar may be formed in contraction. Tentacles rather long, tapered, moderately stout, versatile, often perforated, banded; 96 or more in the larger specimens, in two or three crowded marginal rows, the outer ones distinctly shorter and smaller. Disk very changeable, convex or concave. Mouth often raised; siphonoglyphs two; lips with numerous (about 14) small folds on each side.

Color variable, usually bright and translucent; column generally pale pink or flesh-color, irregularly splashed and mottled with rose red, carmine, or scarlet, except just below the margin, where there is usually a zone without spots; sometimes the whole surface is plain flesh-color, or pale greenish white. Tentacles usually pale pink or flesh-color with three bands of rose-red or carmine, of which the distal occupies the tip; from the proximal band a narrow line of red usually runs along each side of the base to the outer part of the disk, where it may form a short radial line; but these are often interrupted, so as to form a circle of red spots on the disk; another circle of small red spots usually occurs near the mouth. There is usually a flake-white spot at the inner base of each tentacle.

was not originally referred to the genus by Edw. and Haime. The same is true of *P. Peruviana* (Less.), adopted as type by Andres.

Alloactis, new genus. Type *A. excavata* (Hert.). Paractidæ with the circular muscles of the tentacles unequally developed at the base, it being much thickened on the inside. Wall sulcated. No mesenterial stomata.

A. excavata was taken in 1375 fathoms by the Challenger.

The ground-color of the disk is usually pale pink, but it may be pale cream-color or greenish white. The mouth is nearly always surrounded by a narrow circle of bright rose-red, orange-red, or scarlet on the lips; the angles are usually brighter scarlet or vermilion; inside of mouth pink or pale salmon.

In transverse section the wall and base are very thin. The mesenteries are also unusually thin, owing to the very feeble development of the longitudinal muscles; 16 or more pairs are perfect and nearly equal in the larger specimens, but the number is variable; sometimes 24 or more pairs join the upper part of the stomodæum, or even lower down; but only 16 pairs usually join it at its proximal end; those of the 4th cycle are small and often more or less irregularly developed, in the different sextants. Usually, in the larger specimens, a pair is regularly developed between all the pairs of perfect ones; in the stomodæal region these are about one-third as broad as the perfect ones and have longitudinal muscles. All of the perfect and part of the imperfect ones bear gonads, near the base. Some small ones of the 5th cycle also occur near the base. The sphincter muscle is mesodermal, diffuse, elongated, gradually becoming larger distally, and club-shaped or retort-shaped. The mesoglœa is considerably thickened in the region of the sphincter. The two siphonoglyphs are continued downward by a short lobe at each angle of the stomodæum, which is large, with about 16 plications on each side.

Height of column, in full expansion, 2 inches (50^{mm}); diameter of disk about 1·5 inches (37^{mm}); length of longer tentacles about ·6 inch (10 to 15^{mm}).

Bay of Fundy; Eastport Harbor; Johnson's Bay, near Eastport, Me. Not rare in 8 to 35 fathoms, on stony bottoms. Taken by me in 1861, '63, '64, '68, '70, and 1872.

Specimens of this species were described by me in 1864 (Revis. Polyps, pp. 19 (var. 4), 20) as a variety or young of *Urticina crassicornis*, which it closely resembles in form and color. At that time, however, I stated that it agreed closely with *Stomphia Churchiæ* Gosse. The anatomical characters of the latter were, of course, then unknown.

There can be little doubt that *S. Churchiæ* is identical with our species,* but the latter name is later than *carneola*, in case they prove identical when directly compared. It has been thought by some writers that *Actinia coccinea* Müll. is identical with *S. Churchiæ*, but of that I cannot judge. Carlgren also takes this view in the appendix to his article, but according to Gosse and others that species is a *Sagartia*.

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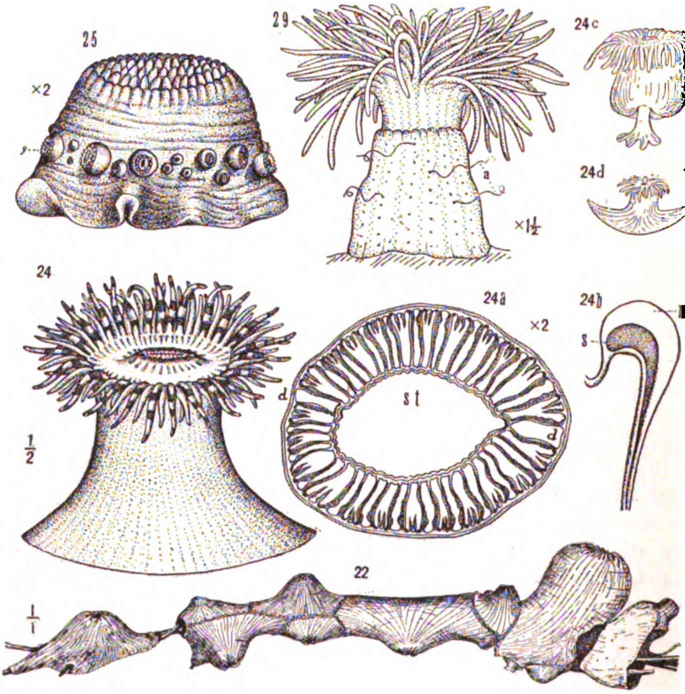
* The slight differences between the anatomical description given by Carlgren and my own are doubtless due partly to the greater size of my specimens and partly to the modes of preparation, and to individual variations.

There can be no doubt of the identity of my specimens with Stimpson's *carneola.* It not only agrees with his description, but Dr. Stimpson was with me on several occasions when we dredged it at Eastport, Me., in considerable numbers, and he positively identified it as his species, but he, at that time, agreed with me that it probably was a variety of *U. crassicornis.*



Explanation of figures.

FIG. 22. *Raphactis nitida* V. A cluster of nine, surrounding stems of hydroids. Somewhat less than natural size, from alcoholic specimens.

FIG. 24. *Stomphia carneola* (St.). Side view of a large specimen, one-half natural size, from life. 24*a*. Section of same, with 23 perfect pairs of mesenteries, × 2; *st*, upper part of the stomodæum; *d. d*, directives. 24*b*, Longitudinal section of the marginal region of the wall; *m*, thickened mesoglœa of the collar; *s*, section of sphincter muscle. 24*c*; 24*d*, two characteristic forms assumed in life, when unattached, ¼ nat. size.

FIG. 25. *Epiactis prolifera* V. One of the types, × 2; *y*, young attached to sides.

FIG. 29. *Sagartia leucolena* V. Partly contracted, showing invagination below margin; *a*, acontia; from life.

All the drawings are by A. H. Verrill, except 24, 24*c*, 24*d*, which are from sketches by the author.

Paractis nivea (Less.). Figure 16, page 146.

Actinia nivea Lesson. Voy. Coquille, p. 81, pl. iii, fig. 8, 1832.
Sagartia nivea Verrill. Trans. Conn. Acad., i, p. 485, 1869 (*non* Duerden).
Aiptasia nivea Andres, op. cit., p. 175, 1884.

The wall in most parts of the column is very thin, but strong and parchment-like, often with smooth satin-like appearance, and when seen with a lens it may appear somewhat fibrous transversely; it shows about 48 mesenterial lines. In contraction it is variously, but rather closely and deeply, transversely wrinkled, showing that it is a much elongated species when in full expansion, The sphincter muscle is rather broad and diffuse, without a very definite outline. The mesoglœa is thickened near the summit so as to form a fold in contraction; another fold often occurs lower down, when strongly contracted, the upper part being somewhat invaginated into the lower. In these examples there may appear to be a second sphincter, due to the longitudinal contraction.

The perfect mesenteries are usually in 12 pairs, but vary from 12 to 16, and rarely 24 pairs, all of which appear to bear gonads. A variable number of small mesenteries occur between the perfect ones; usually those of the third cycle are well developed and bear gonads, but those of the fourth cycle are very rudimentary and do not bear gonads; small rudiments of the fifth cycle may also occur. The longitudinal muscles of the perfect mesenteries are not very thick, but cover most of their breadth.

Tentacles are very numerous and may be entirely infolded and concealed; in the larger examples there are over 120; they are closely crowded in four or five rows; even in alcohol they are rather long and slender with acute tips; the outer ones are much smaller than the inner. In some alcoholic specimens, preserved for thirty years, the tentacles, when they have been protected by retraction, still retain a reddish brown tint, but others are pure white. The tentacles in a large number are fully exposed. Probably the color is variable in life.

The larger specimens are 15 to 18^{mm} in diameter; some are 25 to 30^{mm} long, with a diameter of 8 to 10^{mm}.

Callao, Peru, on the bottom of an old vessel that had been more than a year in that port. They were mostly living in the interstices of large clusters of *Discina lævis.*

This species looks like a *Sagartia,* but no acontia were found in numerous specimens dissected, hence I refer it to *Paractis.*

Subgenus *Archactis,* nov. Type *A. perdix.*

Body nearly smooth in expansion, broad, usually cylindrical; base broad, muscular; margin without distinct fold or thickening, in expansion; disk broad, often undulated; tentacles hexamerous, very numerous (up to 300 or more) in many rows, long, tapered, inner ones far from margin, strongly entacmæous. Mouth large, with two siphonoglyphs and many lateral folds. Stomodæum with two large basal lobes, making prolongations of the siphonoglyphs; mesoglœa of wall rather thick, very flexible, strong; ectoderm soft; sphincter muscle very broad, diffuse, mesodermal, moderately thick distally. Mesenteries hexamerous, very unequal, numerous, with broad, thin, diffuse longitudinal muscles; 12 or more pairs perfect; all the mesenteries fertile, except the directives and the rudimentary ones of last cycle.

The following species differs so much from the ordinary species of *Paractis*, that it seems desirable to make it the type of a generic group, especially as the true type of *Paractis* is not yet determined. It is closely allied to *Stomphia*, but lacks the thick collar and sphincter of that genus, and has a thicker column-wall, lower down. The mesenteries are also more graduated in size.

Paractis (*Archactis*) *perdix* Ver. Figure 26.

Urticina perdix Ver., this Journal, xxiii, p. 223, 1882; Bulletin Mus. Comp. Zool., xi, p. 49, pl. vii, figs. 1. 1*a*, 1883; Annual Rep. U. S. Fish Comm., xi, p. 534, pl. v, figs. 19, 19*a*, 19*b*, 1885.

This large and beautiful species has been pretty fully described as to its exterior, in the works cited above. The tentacles are about 384 in an average specimen. Alcoholic specimen of medium size (diameter of column 1·5 to 2 inches) when dissected had five complete hexamerous cycles of paired mesenteries, and rudimentary ones of the sixth cycle at the periphery of the disk (formula, $6+6+12+24+48+96 = 192$ pairs). Of these, 94, or all belonging to the first five cycles, except the two pairs of directives, are fertile and bear large gonads; those of the first three cycles are mostly below the stomodæum, while those of the 4th and 5th are in the stomodeal region and extend nearly to the disk; a few of the narrow rudimentary mesenteries of the 6th cycle also bear small gonads, close to the disk. Near the lower part of the stomodæum there are 12 pairs of perfect thin mesenteries, the six lateral primaries being distinctly wider and stouter than the rest. Higher up 12 more pairs (3d cycle) may join the stomodæum and differ but little from those of the 2d cycle; close to the disk some of those of the 4th cycle may join the stomodæum. Lower down those of the 3d and 4th cycles are free and successively somewhat narrower, though still broad, while those of the 5th cycle are much narrower, but all are regular and fertile. The longitudinal muscles are feebly developed on all the mesenteries; even on the perfect ones they are scarcely thicker than the oblique muscles of the opposite side. They extend over the whole breadth of the mesenteries, in a nearly uniform thin layer; the mesoglœa is thin with only rudimentary muscle-processes.

The stomodæum is long and large, extending down to about midheight of the body; the two siphonoglyphs are very deep, smooth inside, and extend downward as two large pocket-like lobes, far below the stomodæum, and nearly to the basal disk. They are about half as long and nearly half as wide as the central part of the stomodæum. The free parts of the directive mesenteries are therefore short, narrow, and sterile. The walls of the stomodæum are strongly folded and also have, each, about 36 principal interior plications on each side, nearly all of which are dark brown in color, even after being 16 years in alcohol.

The sphincter muscle is mesodermal, very broad, but not very thick, though it forms more than half the thickness of the wall distally, where it is slightly club-shaped, in section, and blunt at the end; it extends down about half the height of the column, gradually becoming thinner, but locally thickened where the body is most contracted. The wall is flexible, but strong, and of moderate thickness; the mesoglœa is rather thick, compact and nearly even; not much thickened at the collar; the ectoderm is rather thick, soft, and so folded by the fine wrinkles, running in both directions that the whole surface often appears to be covered by small wart-like, irregular elevations and papillæ, but the mesoglœa does not rise into them. When living it was smooth, or nearly so, in full expansion. The whole body contracts very much in alcohol, and more so than most species. The collar is but slightly marked even in the contracted specimens, and is not apparent in the live ones; the fosse is also very slight; the margin is tentaculate; the outer tentacles, in alcohol, are very short and conical.

This remarkable species was taken on the Gulf Stream slope, south of Martha's Vineyard, in 62 to 192 fathoms. It lives well in aquaria. One large specimen was kept two months. On one occasion it caught and swallowed a very active golden mackerel (*Caranx*) a foot in length, though several inches of the fish's tail projected out of the mouth for some hours.

Synanthus mirabilis Ver. Figure 23.

This Journal, xviii, p. 474, 1879; Bulletin Mus. Comp. Zool., xi, p. 48, 1883, pl. vi, fig. 9; Ann. Rep. U. S. Fish Com., p. 534, 1885.

Two alcoholic specimens are now figured; these are united by sutures, side by side, and together surround a branch of *Paragorgia*, like a ligature, making a deep constriction, as in the original types. Tentacles retractile, about 96, rather stout, closely crowded in four or five rows. Wall smooth, and covered with a soft ectodermic layer, which rubs off very easily, leaving a smooth tough surface, slightly sulcated near the summit, and with about twelve principal convergent ridges and some smaller ones alternating. These do not form very definite structures, but are apparently due entirely to contraction. Wall in the region of the collar very thick and firm, with thick mesoglœa. Sphincter muscle mesoglœal, much enlarged in the collar, gradually thinning out below.

Mesenteries numerous; about 48 pairs may join the outer edge of the disk, of which some of the smallest bear distally small gonads. Only six perfect pairs join the middle of the stomodæum; these are fertile at base;* those of the second cycle are nearly as wide and carry large gonads; those of the third cycle are narrow, partly fertile; those of the fourth are rudimentary, except at the outer edge of the disk. The longitudinal muscles of the mesenteries are thin, but cover most of their breadth; they are largest on the lateral primaries. There are two pairs of directives and two siphonoglyphs well developed, but one is deeper. The stomodæum is short. Mouth has six principal folds on each side. No acontia could be found, nor any cinclides.

Height, in alcohol, about 4^{mm}; diameter of column 10 to 12^{mm}.

Off Nova Scotia, Gloucester fisheries, Lot 534.

The apparent total lack of acontia and cinclides compels me to place this genus in the *Paractidæ.* Its thickened collar and large sphincter are much like those of *Stomphia* and *Raphactis.* From the last it differs mainly in lacking the thickened, solid, submarginal ridges. Quite likely larger examples might have 12 perfect pairs of mesenteries, as those of the second cycle are wide, in our small specimens. In *Paractidæ* the number of perfect pairs nearly always increases with age. It also has the habit of *Gephyræa*, but the latter is a Sagartian.

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* Under the name *Paractis lineolata* (Dana, sp.) McMurrich has described a species with only *six* pairs of perfect mesenteries, which are also sterile, as in many of the *Sagartiadæ.* It had about 96 tentacles and four cycles of mesenteries, while Dana's species had but 24 tentacles, though seemingly of larger size. The differences combined with the fact that Dana's species was from the shore of Orange Harbor, while the Albatross specimens were from N. lat. 8° 16′ 30″, in 47 fathoms, render it almost incredible that they can be the same. The latter may possibly be a *Sagartian* which had lost its *acontia*, as often happens. To avoid confusion I propose to name it *Antiparactis dubia*, considering the genus as a doubtful *paractid*, characterized by the six pairs of sterile perfect mesenteries. It has a large mesodermal sphincter muscle in a thickened submarginal fold of mesoglœa, as in many *Paractidæ* and *Sagartiadæ.* Its base is not amplexicaul.

Ammophilactis, **gen. nov.** Type *A. rapiformis* (Les.).

Paractid actinians adapted for living in sand, and having a small base, with a round or obtuse limbus in contraction. Wall thin, smooth, tough, often translucent and showing the insertions of the mesenteries. A strong mesoglœal sphincter muscle, situated in a thickened part of the wall, which, in contraction, forms a sort of thickened collar, protecting the submarginal, invaginated region; the latter has a very thin wall, covered with numerous minute, rounded, adhesive papillæ, which are not always visible in expansion, but are capable of attaching sand grains. Tentacles tapered, numerous (up to 144 or more), in several rows; the inner ones are far from the margin, larger, but not much longer than the outer ones. Mouth large, with two siphonoglyphs, and with 12 to 16 folds on each side.

Mesenteries numerous; 24 pairs are perfect, and have broad, strong muscles. Imperfect mesenteries of the fourth cycle are also muscular; those of the fifth cycle are feebly developed. The perfect and the larger imperfect mesenteries bear gonads.

Differs from true *Paractis* in its elongated body; the reduced and feeble base; submarginal band of suckers, etc.

Ammophilactis rapiformis (Les.) Ver. Figures 28, 33.

Actinia rapiformis Les., Proc. Phil Acad., I, p. 171, 1817.
Paractis rapiformis Edw. & Haime, I. p. 249, 1857.
Actinia (?) *rapiformis* Ver., Revision Polyps, p. 35, 1864; Proc. Boston Soc. Nat Hist., x, p. 338.
Paractis rapiformis Ver., Invert. Vineyard Sd., p. 444. [738]. 1873; this Journal, III, p. 436. 1872 (descr.). Dana, Coral Islands, Ed. 2, p. 23, cut, 1874. Andres, op cit., p. 262.
Sagartia modesta Dana, Coral Islands, Ed. 1, p. 23, figure, 1872 (*non* Verrill).

A living specimen found by me in a tide-pool at Outer Island, near New Haven, had the following characters in life: Height of column in extension, about 3 inches (80^{mm}); diameter of disk 1 inch (25^{mm}); of column ·5 to 1 inch (12 to 25^{mm}; of base about ·5 inch (10 to 12^{mm}); length of tentacles ·5 to 1 inch (12 to 25^{mm}).

The longer tentacles are equal to the diameter of the disk, or even exceed it; they are slender, tapered acute, arranged in several rather crowded rows, the inner series of six are about midway between the mouth and margin; the next six only a little farther outward; the outer ones are only a little shorter, crowded; mouth oblong or elliptical with about 14 folds on each side and a siphonoglyph at each end. Color of column translucent yellowish white with the mesenterial sutures showing through, as paler lines. Tentacles pale gray, with a brownish central line and white tips; each has also, on the inner side, near the end, a flake-white linear median spot or line, with another like it near the middle, and a less evident roundish white spot on the inside, near the base; at the base, on each side, there is a lunate spot of dark brown, the two nearly meeting in front; from each pair of these spots two narrow lines of white, edged with orange, run toward the mouth, but most of them do not quite reach it, but those of the inner rows reach the lips. The disk is grayish white with a halo of pale bluish around the mouth.

This specimen was loosely attached to algæ and probably had been recently washed out of the sand by a storm.

Another specimen from near New Haven (coll. J. D. Dana), of about the same size, preserved in alcohol, has 24 pairs of perfect mesenteries, nearly equally developed, two pairs being directives. Between each pair of perfect ones there is a pair of imperfect ones, about one-third as broad and with strong muscles. In some places rudiments of another cycle can be found. The longitudinal muscles of the perfect mesenteries are strong and extend over most of their breadth, being most thickened at about the inner third. Gonads are borne both by the perfect and imperfect mesenteries. The wall is smooth, thin, but tough, and somewhat parchment-like in alcohol, not much wrinkled, though sometimes fluted longitudinally; the mesenteries show through by translucency, as whitish lines. In contraction, there is a thickened collar below the margin, containing a rather strong, diffuse, mesoglœal sphincter muscle. Between the collar and the margin the wall becomes very thin and soft and is covered with numerous very small adhesive papillæ, or suckers.

The mouth has two siphonoglyphs and about 12 principal folds on each side with several other smaller ones, making about 16. The tentacles number about 120; they form four or five rows, the outer ones crowded. The marginal tentacles are smaller than the inner ones, but not much shorter. The basal disk is small, thin, and without a definite margin, the limbus being obtusely rounded.

This is one of the specimens figured by Professor J. D. Dana (Coral Isl., p. 23), but his figure of the mesenteries is entirely diagramatic and was not made from a section.

Phelliopsis, gen. nov. Type *P. Panamensis* V. (See p. 144.)

General appearance and habit as in *Phellia*. Column much elongated, but capable of contraction to a short cylindrical, pyriform, or ovate form and of infolding the summit so as to conceal the tentacles, though these are often exposed in preserved specimens. Base with a well developed adhesive disk, about as wide as the column. Cuticle of the scapus thin and closely adherent; integument of alcoholic specimens strongly and closely wrinkled transversely and longitudinally, but without distinct suckers or verrucæ. Submarginal zone without cuticle, plicated in contraction. Tentacles numerous, strongly entacmæous, arranged in several circles.

Mesenteries numerous, hexamerous, very unequal. Six pairs of perfect and fertile mesenteries* in the type. These have very thick and strong longitudinal muscles. Sphincter muscle rather wide, diffuse. No acontia could be found in several specimens dissected.

The apparent lack of acontia and cinclides compels me to refer this genus to the *Paractidæ*, though it has the appearance of a *Phellia*.

Phelliopsis Panamensis Ver. Figures 37, 37*a*.

Phellia Panamensis Verrill, Trans. Conn. Acad., I, p. 490, 1869. Andres, op. cit., p. 127, 1884. Hertwig, Voy. Challenger, vi, p. 81, 1883.

The original description of this species is pretty complete, as to external characters.

The tentacles are in four or five close circles; they vary from 72 to 96 or more; they are strongly sulcated by contraction. In longitudinal sections the stomodæum is short, strongly plicated, and has two siphonoglyphs, while the elongated region below it is largely occupied by the 12 thick and very muscular, perfect mesenteries and the large gonads that they bear, extending from the stomodæum to very near the base (fig. 30, *o*). The imperfect mesenteries, between these, are very much narrower and thinner; those of the second cycle bear smaller gonads, on the upper parts in the stomodeal region. In the larger specimens seven pairs of small imperfect mesenteries intervene between the perfect pairs, there being four hexamerous cycles. The small mesenteries decrease in breadth successively; those of the second and third cycles have well defined thickened, but narrow, muscles; those of the fourth are very narrow.

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* In my original description of the type species (1869), I stated that the large primary mesenteries were very muscular and fertile, but Hertwig (Voy. Challenger, vi, p. 81, 1883), when little else had been published in regard to the anatomy of any *Phellia*, expressed more than a doubt as to the correctness of my statement. He wrote, in regard to it: "This so flatly contradicts all observations on the distribution of the reproductive elements in the Actiniæ that Verrill must somehow have been mistaken." "His observations are of no use for another reason, namely, that he says nothing about the relation of the septa to the œsophagus."

As to the last remark, I originally stated that the fertile septa were the large ones, "corresponding to the 12 large inner tentacles" and presumed that every naturalist would know that such mesenteries always join the œsophagus, or are "perfect" to use Hertwig's term. His remark, however, illustrates the uselessness of generalizing as to the internal structure of genera of Actiniæ that one has not dissected. This has also been well shown in the case of the species referred to *Sagartia*.

As for those actinians that belong to the true Sagartian *Phellinæ*, it is now known, from the studies of Danielssen and others, that in many of the species the perfect mesenteries are fertile, while in others they are sterile. But it is not known whether these differences may not be due to age or to the season of the year, in many actinians. Perhaps the gonads develop successively on the different cycles of mesenteries in such cases.

The species that Hertwig examined anatomically and described, in the work cited, as *Phellia pectinatus* is not a *Phellia*, but probably belongs to *Chondractinia*.

The wall is flexible, but moderately thick and tough, owing to the well developed but irregular mesoglœa, which rises internally into irregular lobulate processes, corresponding to the external plications and wrinkles. It becomes thin and soft in the capitulum. The circular muscle is distinct and continuous, but thin. The sphincter in section is elongated, becoming thicker near the upper edge (fig. 30, *s*). There is a large mesenterial foramen in the stomodeal region (fig. 30, *f*).

Family BUNODACTIDÆ Ver. See No. II, p. 42.

The principal distinction of this family, as compared with *Paractidæ*, is the sharply circumscribed endodermal sphincter muscle, which is often only attached to the wall by a part of its outer surface. Its outline, in section, is usually ovate or subcircular, but it varies in form in the same species, according to the degree of contraction. Many Phyllactidæ (*Asteractis*) have a similar sphincter, and it is probable that they will hereafter be united with this family. The mesenteries and tentacles may be either hexamerous, decamerous, or octamerous, and are often irregular in number and arrangement.* There are usually two pairs of directives and two siphonoglyphs, but may be only one; sometimes there are three, or even four. These variations may occur in one species. Perfect pairs of mesenteries are usually 12 or more, and generally all are fertile and strongly muscular. Verrucæ or adhesive suckers are usually present on the column, but not always. No acontia are present.

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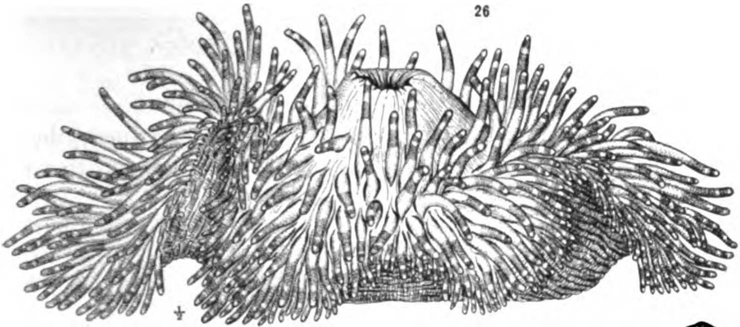
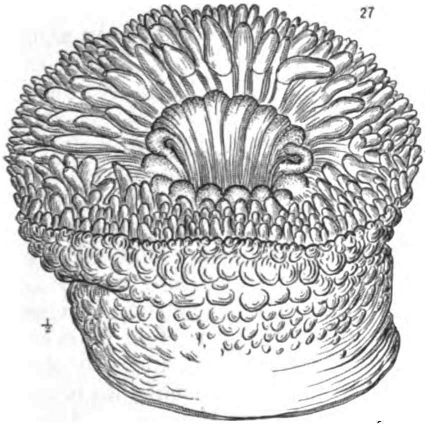
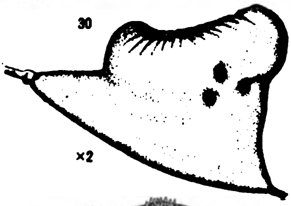
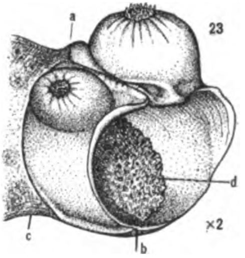
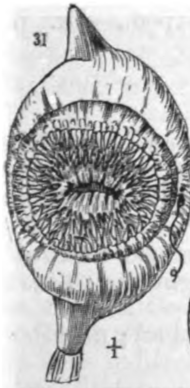
* As a rule, the anatomical investigations of actinians have, up to this time, been based on a single specimen, or else on a very few, usually collected at the same season of the year, so that we do not know whether the gonads do, or do not, develop successively on the different mesenteries, even in common species. Moreover, in several cases where considerable numbers of specimens of one species have been dissected, variations often of the most remarkable kind have been found in the arrangement and number of the mesenteries; number of pairs of directives, and of perfect mesenteries; form of the sphincter, etc. This is especially the case in several species of *Sagartia*, *Metridium*, *Bunodactis*, *Urticina crassicornis*, etc. Of the latter, I have found many specimens hexamerous, both as to tentacles and mesenteries; many others decamerous; some octamerous; and a few irregular or unequally developed on opposite sides. Thus it seems that such internal anatomical characters are often as variable and no more reliable than external characters in certain groups of Actinaria.

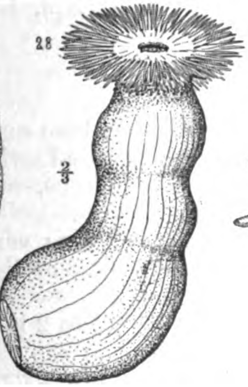












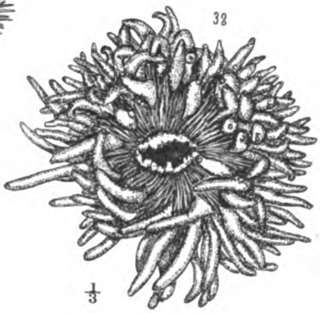


FIG 23. *Synanthus mirabilis* V. ×2; *a*, *b*, sutures between two individuals; *c*, branch of *Paragorgia*; *d*, constricted and broken end of same type

FIG. 26. *Paractis* (*Archactis*) *perdix* V. ⅓ size, from life, in extreme expansion.

FIG. 27. *Actinostola callosa* V. ½ size, from life, type.

FIG. 28. *Ammophilactis rapiformis* V. ⅔ size, from life.

FIG. 30. *Stephanauge abyssicola* Ver. ×2; side view, from an alcoholic specimen, showing cinclides.

FIG. 31. The same, partially expanded; type of *Actinauge nexilis* V.

FIG. 32. *Urticina crassicornis*, ⅓ nat. size; hexamerous variety, from a photograph of a living specimen.

The drawings are by A. H. Verrill; figs. 26, 27, 31 are modified from studies by J. H. Emerton.

Anthopleura Japonica Ver., sp. nov. Figure 39.

The body is contracted in alcohol to an ovate form, the disk and tentacles being concealed and the base reduced to a small concave area, but it is somewhat mutilated.

Above the middle the wall is covered with fine transverse wrinkles and has unequal vertical rows of concave adhesive suckers. Higher up these are replaced by hollow, round or conical verrucæ, and then by more prominent papillæ, the upper ones becoming lobulated more or less on the outer and under sides by small papillæ. Of marginal papillæ there are 48 rows, larger and smaller, but of these rows only about 36 are prolonged downward by rows of suckers. Some of the marginal papillæ seem to be perforated. The mouth has two siphonoglyphs. Tentacles about 96, rather stout, tapered arranged in three or more crowded rows. Probably they were rather elongated in expansion. The sphincter muscle is endodermal, rather large, ovate in section, sharply circumscribed.

Mesenteries are in four regular hexamerous cycles, all much thickened; those of the 3d and 4th cycles are successively narrower and smaller; 12 pairs are perfect and nearly equal including two pairs of directives. All bear strong, thickened pleated longitudinal muscles; those of the perfect pairs extend over more than two-thirds of their breadth and are thickes about the middle. All, or nearly all, the mesenteries bear larg gonads. Some of them are mutilated in the type. The colo in life was not noted.

Simoda, Japan, U. S. N. Pacific Expl. Exped.,—Dr. Wm Stimpson, 1854.

Bunodactis Manni Ver., sp. nov.

Column more or less cylindrical; base somewhat expanded Tentacles numerous, in several crowded series, tapered, acute Column closely covered with numerous, small, rounded verrucæ, arranged in many vertical series.

Color of column usually dark green; verrucæ dark red o brown; disk, around the mouth pink or light red; tentacle dark red.

Height, in expansion 25 to 50^{mm} (1 to 2 inches); diameter o disk 35^{mm} or more.

Hawaiian Islands, at and below low water mark in crevice of rocks and attached to stones.

The above description was prepared many years ago, an I now find no specimens in our collections to correspond wit it. It was named in honor of my friend, Mr. Horace Mann a young botanist who visited the Hawaiian Islands to mak botanical and zoological collections and who contributed largel to a knowledge of the botany of the islands, but died befor his work was finished.

ART. XXII.—*A Study of some American Fossil Cycads.* Part I. *The Male Flower of Cycadeoidea;* by G. R. WIELAND. (With Plates II–IV.)

Introduction.

THE Mesozoic formations of the Rocky Mountain region, especially around the Black Hills, have furnished few fossil forms of higher scientific interest than the silicified trunks of Cycads there preserved in great perfection. Most of these specimens retain both their external features and internal structure in such minute detail as to make possible a more complete biological study of the entire group than has hitherto been attempted.

There is now in the Museum of Yale University a series of these rare fossils, including several hundred individuals represented by complete, or nearly complete, trunks. For this superb collection of fossil Cycads, Science is indebted to the generosity and untiring zeal of Professor Marsh, who has also given the writer the privilege of examining the entire series.

The exact geological age of these Cycads is still in dispute, but their general position is in the middle Mesozoic, and is most probably Jurassic, as suggested by Professor Marsh in the following statement:

"In the Rocky Mountain region, especially around the margin of the Black Hills, a definite horizon likewise exists, in which great numbers of Cycad trunks are found in remarkable preservation. These Cycads resemble most nearly those from Maryland, found in what I term the Pleurocœlus beds of the Potomac formation. In the Black Hills, the age of the horizon has not been accurately determined. * * * Until recently the Cycads of the Black Hills, although of great size and remarkable preservation, have not been found actually in place. In the large collection of Cycads belonging to the Yale Museum, a few have been discovered apparently where they grew, and systematic investigation will doubtless show that the various localities where these fossils have been found around the Black Hills are all in one horizon. The evidence now available indicates its Jurassic age, and suggests that it is essentially the same as that of the Cycad beds in Maryland, which I regard as a near equivalent of the well-known Cycad horizon in the Purbeck of England."*

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* The Jurassic Formation on the Atlantic Coast.—Supplement.—This Journal, vol. vi, p. 115, August, 1898. See also, the present number, p. 229.

Prof. L. F. Ward, however, has recorded his opinion that this horizon is Cretaceous.* While these fossil Cycads must eventually prove of much greater value to stratigraphy than isolated leaves, as pointed out by Prof. Marsh, their present interest is mainly of a structural character.

The living Cycads constitute one of the most ornate and characteristic orders of plants, and, occupying, as they do, a position on the border-land between the higher Cryptogams and lower Phanerogams, their ancestral relationship is of considerable interest in itself, though but little progress has yet been made in working out their phylogeny, owing largely to imperfect knowledge of the fossil forms.

The Male Flower of Cycadeoidea ingens, Ward.

The male fructification of fossil Cycadean trunks has not hitherto been determined with certainty. An element of doubt surrounds the identity of the separate inflorescences usually held to have been derived from extinct *Cycadeæ*, due to the fact that the Mesozoic Cycads were accompanied by a rich, varied, and closely related coniferous vegetation. In the absence of microscopic characters, it becomes a matter of much difficulty to separate with certainty the fructifications of Cycads from those of some Conifers.

Previous observations on this subject are hence quite limited. Of the supposed fossil Cycadean male fructifications, the pyriform axis described by Williamson[5] has given rise to the most discussion. While it is not necessary to review the literature on this subject here, it may be mentioned that Seward,[14] after declaring his belief that the Wealden examples of *Williamsonia* are generically identical with *Bennettites*, writes as follows:—"As regards the question of male and female inflorescence, I am unable to recognize any sexual differences in the various examples from the Wealden beds, and there does not seem to be any good reason for regarding the so-called male *Williamsonias* among the Jurassic specimens as in any way proved to be of that nature. In comparing *Williamsonia* with *Bennettites* we have to rely solely on the female inflorescence of the latter plant, and it would seem, so far as our present evidence goes, we have more reason for speaking of *Williamsonia* as the female inflorescence. As to the nature of the male inflorescence we are still without satisfactory evidence." As will be shown later, the present investigations add a strong degree of probability to this view, if they do not indeed demonstrate its correctness. The reviews of Solms-Laubach,[6] and of Schimper[7] who alludes to the male axis of *Williamsonia* as a *Pandanus*-like form, may also be consulted.

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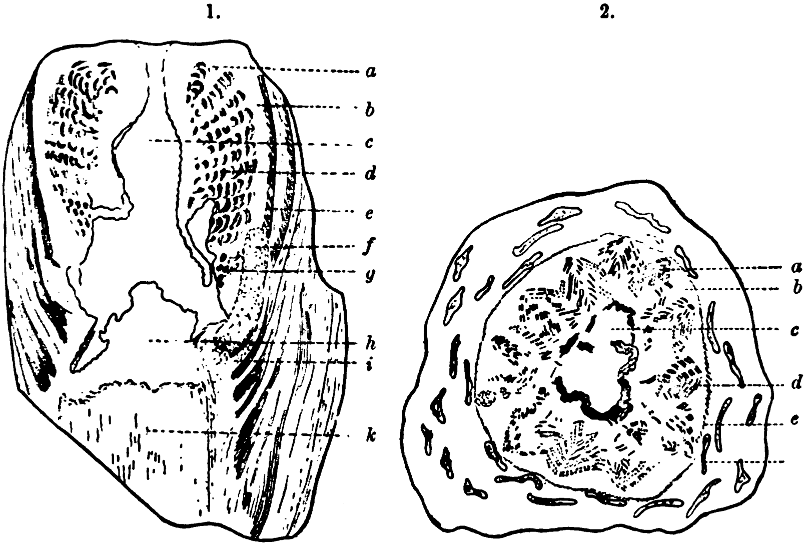
* The Cretaceous Rim of the Black Hills.—Journal of Geology, vol. ii, pp. 250–266, 1894.

The principal loose fossil fruits usually referred to by paleobotanists as male fructifications of Cycadean origin are *Androstrobus Balduini*, Saporta,[4] and *Zamites familiaris*, Corda.[3] Still other and more problematical forms are mentioned by Seward,[14] and Solms-Laubach.[9] In no case, however, is the microscopic structure preserved, or a knowledge of these forms at all complete. There is, therefore, no direct basis for comparison between these conical fruits and the capsular male fructification of *Cycadeoidea* here discussed.



Male flower bud of *Cycadeoidea ingens*, Ward.
FIGURE 1.—Diagram of longitudinal section.
FIGURE 2.— " transverse "

a. group of sori; *b*, fleshy outer wall; *c*, central cavity; *d*, a sorus; *e*, bract hairs; *f*, undetermined body; *g*, basal sorus; *h*, receptacle; *i*, involucral bract; *k*, peduncle.

Both figures are natural size.

The type specimen of *Cycadeoidea ingens*, Ward,[28] which bears the beautiful flower bud here described, is the type of the species, and is a magnificent trunk, nearly perfect, weighing 304 kilograms (671 pounds). In Plate II, it is represented with the flower bud still in position near the summit, where it appears as a conelike projection 3·5 cm in height. Sections of this bud are shown in Plates III and IV. The trunk as seen in Plate II is inclined slightly forward to display the bases of a number of other buds of flowers equally advanced in growth, but not wholly preserved.

The main interior structures of this specimen are indicated in the diagrams figures 1 and 2, page 221, based respectively on the photographs of sections shown in Plate III, and in Plate IV, figure 1.

Between this flower bud and the apex of the trunk, distant 15 cm, is a thickly-set mesh of stipulary chaff enveloping a series of finely-preserved, just emergent young leaves, which will be described later.

As removed from the trunk for examination, the general shape of the flower bud was subcylindrical, with a slightly tapering base and a strongly tapering summit. The length, including a considerable portion of the peduncle, was 73 mm, the basal, middle, and apical diameters being 35, 45, and 25 mm, respectively. Laterally it was covered with a series of imbricating involucral bracts, the summits of which had been eroded away. One very noticeable point was the division of the free summit into twelve subequal sectors by radiating lines apparently due to differentiation of tissues.

The upper portion of the peduncle, figure 1, *k*, is seen to be traversed by a series of fibro-vascular bundles, many of which pass off into the involucral bracts. The latter are covered by a mat of fine hairs quite similar to those borne by the involucral bracts of *Bennettites.*[12] A number of much larger and coarser hairs also arise directly from the peduncle, between the bases of the bracts. The position of the receptacle is indicated centrally by nearly clear quartz, lacking well-defined structure, and peripherally by a shoulder-like offset bearing most of the involucre of bracts.

The basal sori, figure 1, *g*, are not fully developed, and are irregularly distributed in pockets. Following this absence of arrangement, there is a soral grouping into eleven planes, which successively increase their angle to the floral axis until the terminal series rises vertically. It should be noted, however, that this arrangement is only apparent in longitudinal radial sections, situated at regular intervals with reference to the plan of the flower. In other sections, the sori are crowded together without a traceable arrangement, and the grouping in planes is obscured.

Inside the fleshy spore-bearing portion of the flower, which may for convenience be termed the soriferal axis, is a central cavity of quite regular form, lined by a druse of quartz crystals, figure 1, *c*, in places resting on a thin layer of chalcedony, which in turn rests on the silicified tissue.

At *f*, figure 1, is shown an undetermined cylindrical body which has its origin on the receptacle, and curves upward round the base of the soriferal axis, passing half-way up its side. A there are at least ten, if not twelve, of these bodies quite regularly distributed in the same relative position, they are in some way connected with the floral plan, though not likely as essential organs.

In figure 2, which is a diagrammatic sketch of the transverse section through the middle of the soriferal axis, based on the photograph shown in Plate IV, figure 1, the plan of the flower is clearly shown. There is first a series of imbricating bracts, the thickly-set hairs of which are not indicated in the sketch. These are in cross section quite thin and scalelike in the middle and upper region of the soriferal axis, especially the interior series. A cross section of the bracts near their origin is seen in Plate IV, figure 2, which represents a section through the base of the flower, about 2 mm below the basal sori. At this height, the cross section of the bracts is approximately of the same form as that of the petioles of the trunk itself.

Inside the involucre of bracts, figure 2, *b*, is the fleshy integument surrounding the cross area of soral distribution, which is approximately that of a twelve-rayed star, with short points and a hollow center. This is a second clear indication that there is a general plan of twelve, the radial lines of the summit previously mentioned being the first. The sori tend strongly to arrange themselves in tandem pairs parallel to the sides of the twelve points, thus forming an approximation to twelve radial series of from four to six parallel V-shaped groups. Only the examination of a series of successive thin sections now being made will show how far the soriferal surfaces are barren or depart from this arrangement.

It is obvious that the fleshy outer wall extends inward as a homogeneous tissue to form most, if not all, of the soriferal surface. Whether or not these surfaces had any connection with a central axis is obscured by the presence of the central cavity mentioned above. There does not, however, seem to have been any such connection. That there is in any case a series of surfaces which must be regarded as the homologues of sporophylls is a point on which botanists will doubtless agree. The discoveries of Ikeno[23] and Webber,[17] and the investigations of Lang,[21] do not leave any doubt as to the correct terminology of Cycadean inflorescence.

The finer structure of these organs must be treated at another time, though it should be explained now that the sori are composed of from twenty to forty clavate sporangia. Each sporangium is about 1 mm in length and $\frac{1}{10}$ mm in diameter, and contains 500 or more rounded or subangular bodies not yet completely studied, but undoubtedly the spores or pollen grains.

With regard to the homology of these structures, several facts are worthy of mention. The radial divisions occurring on the summit are found to persist for a considerable distance downward, and under the microscope are seen to be due to the presence of two lignified layers, a single cell in thickness. They correspond to the twelve vertices of soral distribution mentioned above, and their presence is against the idea that the soriferal axis is derived from the fusion of the sporophylls of a male cone like that, for instance, of *Zamia integrifolia.* Another and much more tenable hypothesis is that the soriferal axis is a series of twelve fused leaves with their sorus bearing pinnules turned inwards.

While it is evident that the inflorescence under consideration represents a development far in advance of that of existing Cycads, the most striking fact observed is the linear distribution of the sori. This is an archaic character most marked in the Carboniferous ferns, especially the *Marattiaceæ*, and their allied forms, living and extinct.

It has probably been the opinion of all botanists, since it was discovered that *Stangeria paradoxa* was a Cycad and not a tree fern, as originally described, that the relationship between the Ferns and Cycads must be an exceedingly close one. All later investigations have tended to strengthen this belief. Scott[20] has recently stated that the evidence in favor of the filicinian ancestry of the *Cycadeæ* must now be considered overwhelming.

It was scarcely to be expected, however, that forms bearing strong testimony on this point should display such a marked combination of advanced as well as ancestral characters.

The further study of the Yale collection promises to afford many new details regarding Cycadean structure and affinity. In addition to the facts presented in this paper, it has been now determined for the first time that the leaf characters of *Cycadeoidea* were approximately those of *Zamia* and *Dioon*, and had the prefoliation of these genera. Moreover, the ancient forms, like the existing Cycads, were diœcious.

In closing, the writer wishes to express his best thanks to Professors Marsh and Beecher for the indispensable aid he has received during the entire course of the present investigations. He is also indebted to Professor Lester F. Ward for valuable suggestions and reference to important literature.

Yale Museum, New Haven, Conn.,
February 20, 1899.

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EXPLANATION OF PLATES.

Plate II.

Cycadeoidea ingens, Ward (type).
Male plant; showing flower bud at summit.
One-sixth natural size.

Plate III.

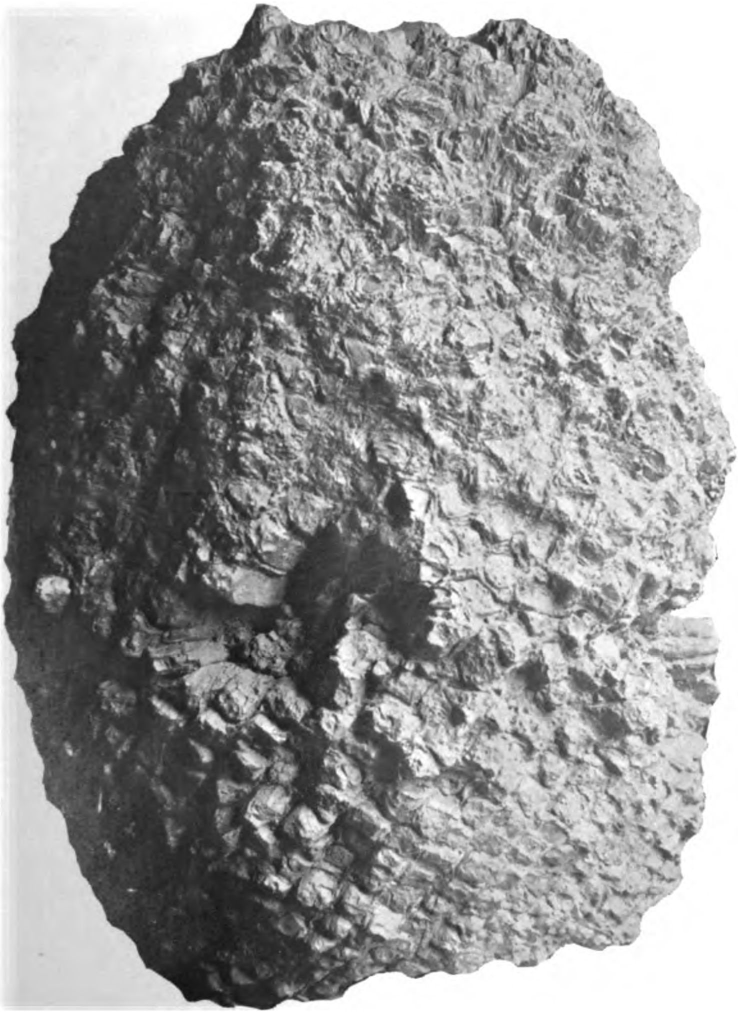
Cycadeoidea ingens; same specimen.
Longitudinal section through male flower.
For details, see diagram in text, p. 221, figure 1.
Twice natural size.

Plate IV.

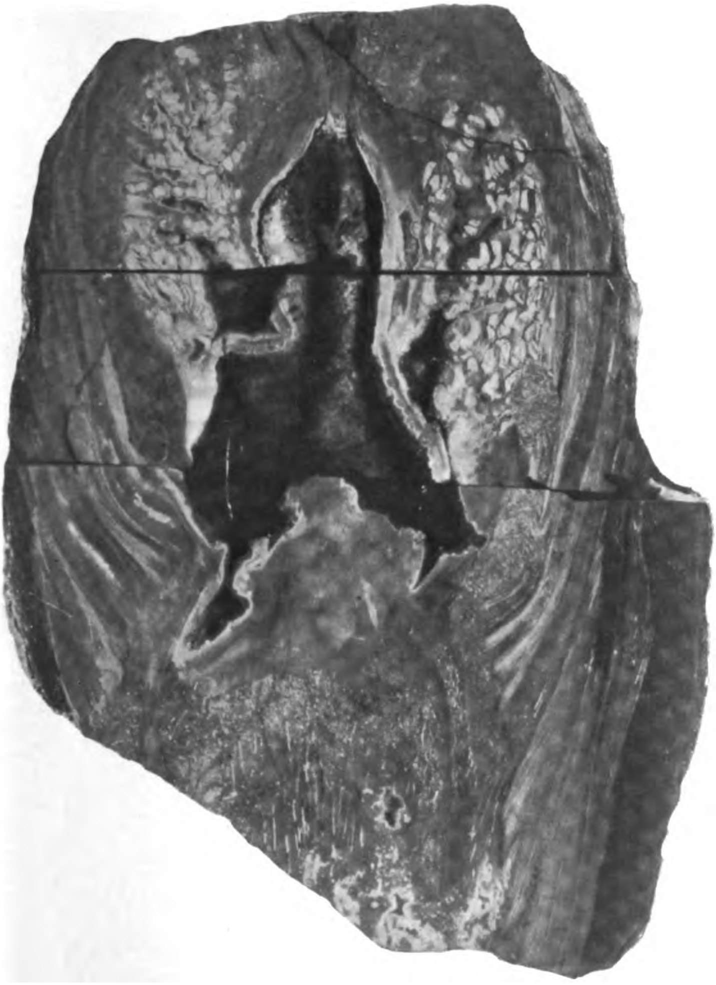
Cycadeoidea ingens; same specimen.

Figure 1.—Cross section through middle of male flower; showing sori and bracts.

Figure 2.—Cross section through base.
For details, see diagram in text, p. 221, figure 2.
Both figures are twice natural size.



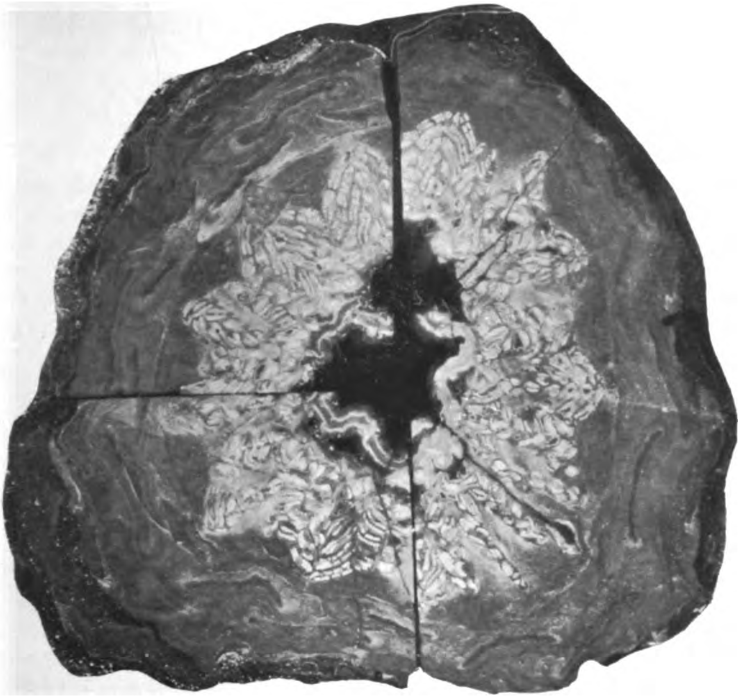
CYCADEOIDEA INGENS, Ward (type).



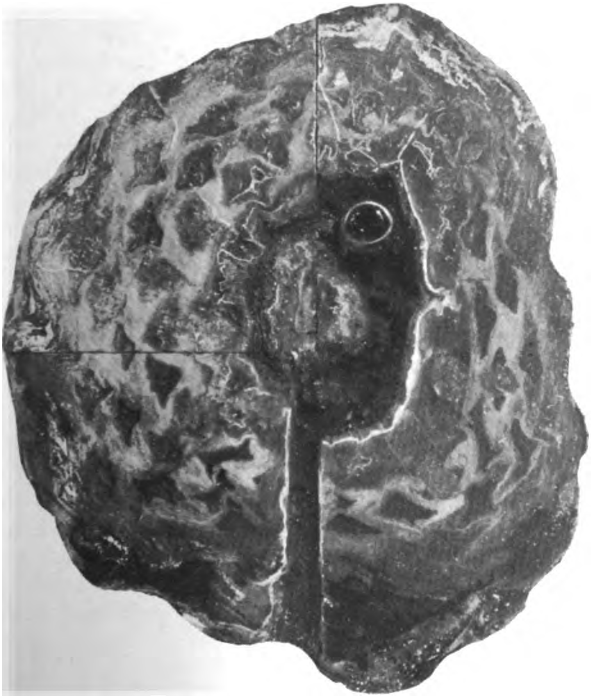
CYCADEOIDEA INGENS; type specimen.

Longitudinal section through male flower.

1.



2.



Cycadeoidea ingens; transverse sections through male flower.

ART. XXIII.—*Footprints of Jurassic Dinosaurs;* by O. C. MARSH. (With Plate V.)

ONE of the most interesting geological discoveries during the past season in the Black Hills region was a locality of footprints evidently made by Dinosaurian reptiles in deposits of Jurassic age. These footprints are the first found in Jurassic strata in this country. They are all tridactyle, of large size, and were evidently made by some of the great Dinosaurs known to have lived during Jurassic time.

The tridactyle footprints hitherto found in this country were nearly all discovered in the Triassic sandstone of the Connecticut Valley, and, as well known, were at first supposed to have been made by Birds. They have since been discovered in essentially the same horizon in New Jersey and also in New Mexico. In the same strata, many other footprints have been found, and among them numerous similar tridactyle impressions, some of which may possibly have been made by birds, but by far the greater number are evidently of reptilian origin. It is an interesting fact that the bones of Dinosaurs found in this horizon of the Triassic all pertain to animals of moderate size, and none are known large enough to have made any of the gigantic footprints so abundant in the Connecticut Valley.

In the Jurassic formation of this country, on the contrary, the osseous remains of Dinosaurs of large size are especially abundant, and among these were not a few bipedal forms that must have made footprints very similar to the so-called bird tracks of the Triassic, but no footprints of any kind have hitherto been found, although diligently sought for in many localities. The present discovery fortunately supplies the much-desired information on this point, and the specimens already secured promise to throw much light on the life-history of this interesting group of reptiles that were the dominant forms of life during Jurassic time.

When these footprints were first discovered, it was naturally supposed they were of Triassic age, as all footprints of similar character known in this country had been found in deposits of that formation. The great development of red Triassic beds in the same region, and their extension in a broad belt around the Black Hills, where they are generally known as the "red beds," all seemed to favor such a supposition. The character of these beds of red shale and sandstone, all evidently deposited in shallow water, as shown by the ripple marks and other well-known features, indicated that footprints and other impressions would certainly be found in them if proper search were made, and this will doubtless prove to be the case.

The large footprints here described, however, are from a higher horizon, and one well within the limits of characteristic deposits of Jurassic age. Their position in the series of Mesozoic strata encircling the Black Hills is indicated in the diagram, on page 229. This section is designed to show the succession of the principal geological horizons above the Paleozoic in the Black Hills region. The lowest beds here represented are the red beds, already mentioned, which are mainly fresh-water deposits, and generally are referred to the Triassic formation.

Next above these comes a series of sandstones, limestones, and shales, containing marine fossils, and named by the writer the Baptanodon beds, from a genus of large swimming reptiles there entombed. This horizon is readily recognized by characteristic marine invertebrate fossils, especially Belemnites, first described from this region about forty years ago by Meek,* who recognized the importance of the horizon. Above these marine beds are extensive fresh-water deposits of Jurassic age, which the writer has called the Atlantosaurus beds, from a gigantic Dinosaur specially characteristic of the horizon. It is in this series of deposits on the southwestern border of the Black Hills that the footprints here described were found, and it is a point of much interest that here, too, are entombed remains of large reptiles that probably made the same footprints, as will be shown later in the present article.

These Atlantosaurus beds, though overlooked by many geologists, have a great development around the margin of the Black Hills, especially along the southern and eastern borders. The bones of gigantic Dinosaurs mark the outcrop of this horizon at various points. The one best known, the writer explored personally in 1889, near Piedmont, South Dakota, and there obtained remains of an enormous Dinosaur, subsequently named *Barosaurus*.† During the past season, important parts of the rest of the type skeleton were secured for the Yale Museum, by G. R. Wieland of that University. With these fossils were found remains of a much smaller species, which may be called *Barosaurus affinis*.

Above the true Atlantosaurus beds is a series of strata of shales and sandstones, the exact age of which is at present a matter of controversy. In this series, there are two or three layers which contain the remains of Dinosaurian reptiles differing somewhat from those below, but especially from those known in the well-defined Cretaceous strata above. The writer has now under investigation for the U. S. Geological Survey, various remains of vertebrate fossils from one of these layers. These fossils, with others secured from different localities in the same region, promise to clear up many of the doubtful points now remaining as to the age of these deposits.

* Proc. Acad. Nat. Sci. Phila., vol. x, pp. 41–59, 1859.

† This Journal, vol. xxxix, p. 85, January, 1890.

The Cycad beds, as they may be termed, from the great umber and variety of remains of this group of fossil plants, re abundantly represented around the rim of the Black Iills, apparently at a higher level, but, as the Cycad remains, lthough distinctive in themselves, have not yet been found bsolutely in place in undisturbed strata, their exact position n the series cannot at present be definitely fixed. Part of his series was formerly referred to the Dakota by various eologists, but this reference is fairly open to question, as the riter has shown elsewhere.*

Recent.			Tapir, Peccary, Bison.
Quaternary.			*Bos, Equus, Tapirus, Dicotyles, Megatherium, Mylodon.*
Tertiary.	Pliocene.	Equus Beds.	*Equus, Tapirus, Elephas.*
		Pliohippus Beds.	*Pliohippus, Tapiravus, Mastodon, Procamelus, Aceratherium, Bos, Morotherium, Platygonus.*
	Miocene.	Protoceras Beds.	*Protoceras, Miohippus, Diceratherium, Thinohyus.*
		Oreodon Beds.	*Oreodon, Eporeodon, Hyænodon, Ictops, Hyracodon, Agriochærus, Colodon, Leptochærus.*
		BrontotheriumBeds	*Brontotherium, Brontops, Allops, Titanops, Titanotherium, Mesohippus, Ancodus, Entelodon.*
Cretaceous.		Ceratops Beds of Laramie Series.	*Ceratops, Triceratops, Claosaurus, Ornithomimus.* Mammals, *Cimolomys, Dipriodon, Selenacodon, Nanomyops, Stagodon.* Birds, *Cimolopteryx.*
		Atlantochelys Beds of Montana Group.	*Atlantochelys, Coniornis.*
		Pteranodon Beds of Colorado Series.	Mosasaurs, *Edestosaurus, Lestosaurus, Tylosaurus.* Pterodactyls, Plesiosaurs, Turtles.
Jurassic.		Cycad Beds.	Cycads, *Cycadeoidea.*
		AtlantosaurusBeds.	Dinosaurs, *Barosaurus, Brontosaurus, Morosaurus, Diplodocus, Stegosaurus, Camptosaurus, Allosaurus.* Mammals, *Dryolestes, Stylacodon, Tinodon, Ctenacodon.*
		Baptanodon Beds.	*Baptanodon, Pantosaurus, Belemnites, Trigonia, Pentacrinus.*
Triassic.		Red Beds.	A few plants.

GEOLOGICAL HORIZONS ABOVE PALEOZOIC OF BLACK HILLS REGION.

Well-marked Cretaceous strata, showing the characteristic ellow chalk of the Pteranodon beds of the Colorado series, are eveloped east of the Black Hills, and contain an abundance f characteristic fossils. These deposits the writer personally xplored in 1889, and proved their identity with the wellnown series along the Smoky Hill River in Kansas.

Next above come the Atlantochelys beds of the Montana roup, well developed, and marked by remains of gigantic ırtles, as well as by characteristic mollusca, and other invertebrates. The top of the Cretaceous east of the Black Hills is ormed mainly by this group. On the western side of the Iills, the highest Mesozoic deposits are the Ceratops beds of the aramie. These form one of the best-marked horizons known n any country, as here occur the gigantic horned Dinosaurs of he genus *Triceratops* and others, as well as numerous small retaceous mammals and birds.

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* This Journal, vol. vi, pp. 107, 115, and 197, August, 1898. See also, the resent number, p. 219.

The Eocene is apparently wanting in the Black Hills region and the Miocene at many points rests directly on Cretaceou strata. The Miocene is represented by three great horizons each marked by an abundance of mammalian remains. Th Brontotherium beds are at the base, the Oreodon beds nex higher, while the Protoceras beds crown the series. The Pliocene is also well developed, as shown in the section, with th Pliohippus beds below and the Equus beds above. Over all the Quaternary and recent deposits are present, marked by a interesting and characteristic fauna.

Below the series here given, the geological structure of th Black Hills, as well known, is briefly as follows: The centra mass is Archean. Outside of this are Silurian strata with th Potsdam sandstone at the base, and limestones of upper Silurian age above. The Devonian is apparently wanting, and th Paleozoic ends with Carboniferous strata, mainly limestone

The age of the Atlantosaurus beds has long been demonstrated to be upper Jurassic, by the conclusive evidence o vertebrate fossils there entombed. Testimony from othe kinds of fossils has not been wanting, and many new facts ar coming to light. One noteworthy instance may be fitl recorded here. Remains of the gigantic Dinosaur *Barosauru* are characteristic of a definite layer in the Atlantosaurus bed on the eastern side of the Black Hills. Just above this laye at various localities, there is a thin seam of arenaceous shal filled with remains of minute *Ostracoda*, and also containing few fishes. As this seam has a definite position, its fossil contents became important in determining its exact age. Amon the fish remains, a perfect tooth was readily recognized a *Hybodus polyprion*, Ag., a characteristic Jurassic fossil, foun in the Dogger, at Stonesfield, England.

A small piece of this shale containing the ostracods wa sent to Prof. T. Rupert Jones of London, the highest authority on the subject, and in a letter to the writer, dated Februar 9, 1899, he reports that in the specimen sent, three specie were represented, namely, *Cypridea punctata*, Forbes, *Metacypris Bradyi*, Jones, *M. Whitei*, Jones, all characteristic o the Purbeck. These new facts need no comment. It wa already known that two of these species, identified by the sam author, occur in the same horizon of the Atlantosaurus beds i Colorado, about four hundred miles further south.

The general characters of the large footprints here describe are well shown in those represented on Plate V, one-sixt natural size. In figure 1, page 231, are given the outlines o three other tracks, one-tenth natural size. These are from th same locality and horizon as those on Plate V. They are al reverse impressions, or natural casts, of the surface immediately over the true footprints, which were made in a soft mu that has itself not been preserved sufficiently to retain th imprints originally made in it.

The interpretation of the various footprints here shown is fortunately a much less difficult matter than that of the huge tridactyle tracks from the Triassic, as in the latter case there was little except conjecture to assist in the investigation. In the present instance, however, it is known that abundant osseous remains of large Dinosaurs are imbedded in deposits of the same age, and in the same general vicinity. Some of these reptiles are known to have been bipedal, and quite large enough to make the footprints now discovered. Moreover, the structure of the feet of some of these animals is sufficiently well known to demonstrate clearly that in walking they must have made footsteps similar to, if not identical with, the fossil specimens here recorded.

1.

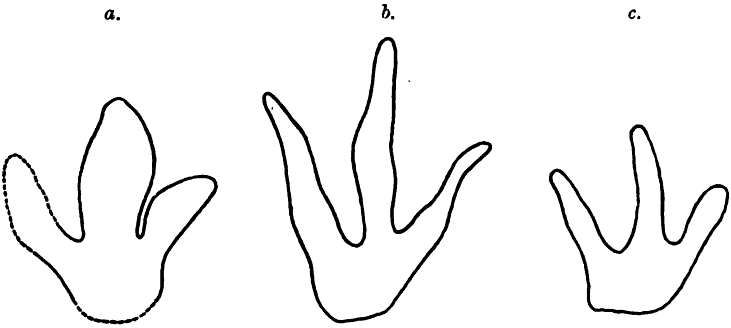


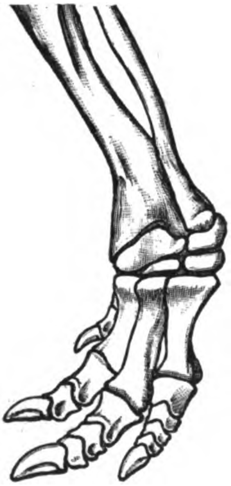
FIGURE 1.—Outlines of Jurassic footprints found with those shown on Plate V. *a*, footprint of large herbivorous reptile; *b*, footprint of large carnivorous reptile; *c*, footprint of smaller carnivorous reptile.
All the figures are one-tenth natural size.

As to the particular reptiles that made the present footprints, we have a hint in the impressions themselves. Some of these show marks of short and wide toes, suggesting that they were made by the robust feet of herbivorous Dinosaurs. The other footprints show impressions of longer and more slender toes, such as are known in the carnivorous Dinosaurs, which lived at the same time and in the same region as the herbivorous forms, and, indeed, preyed upon them. In Plate V, the large figure on the left evidently represents the footprint of a herbivorous Dinosaur, while the small one on the right, with slender toes, was probably made by a carnivorous form. Of the outline figures above, the one with the thick digital imprints (*a*) was doubtless made by a herbivorous reptile, while the other two (*b* and *c*) appear carnivorous in type.

In selecting from this horizon the known Dinosaurs that might have made the present footprints, it would be safe to say that the genus *Camptosaurus*, especially some of its larger species, may be held responsible for the herbivorous footsteps, while its carnivorous enemy, *Allosaurus*, had representatives to which the more slender impressions may naturally be due.

Other genera of carnivorous Dinosaurs are known to have lived in Jurassic time in the same region where these footprints were made, and among them *Creosaurus* and *Labrosaurus* would probably have left similar tracks, although the structure of their feet is not accurately known. *Ceratosaurus*, another carnivorous form, must also be considered, although not known from the region where the footprints occur, while *Cœlurus* is much too small to have made any of the impressions yet discovered. Figures 2 and 3 below show the bones of hind feet of *Camptosaurus* and *Allosaurus*, the Dinosaurs above mentioned.

2.



3.

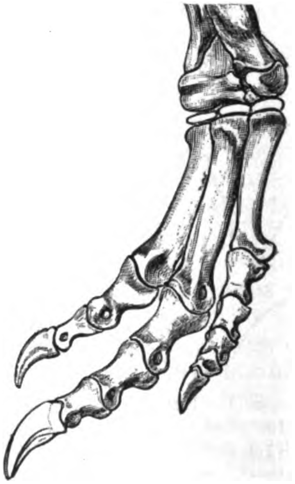


Figure 2.—Left hind foot of *Camptosaurus dispar*, Marsh.
Figure 3.—Left hind foot of *Allosaurus fragilis*, Marsh.
Both figures are one-twelfth natural size.

One point worthy of mention is, that both *Camptosaurus* and several of the carnivorous forms are known to possess, in addition to the three birdlike main digits, a rudimentary toe on the inner side of the hind foot, representing the first digit. This toe, however, was too short to make an impression in ordinary walking on the ground, but might leave a mark where the surface was very soft. No indications of such marks have been found with these footprints, however, and could hardly be expected under the circumstances.

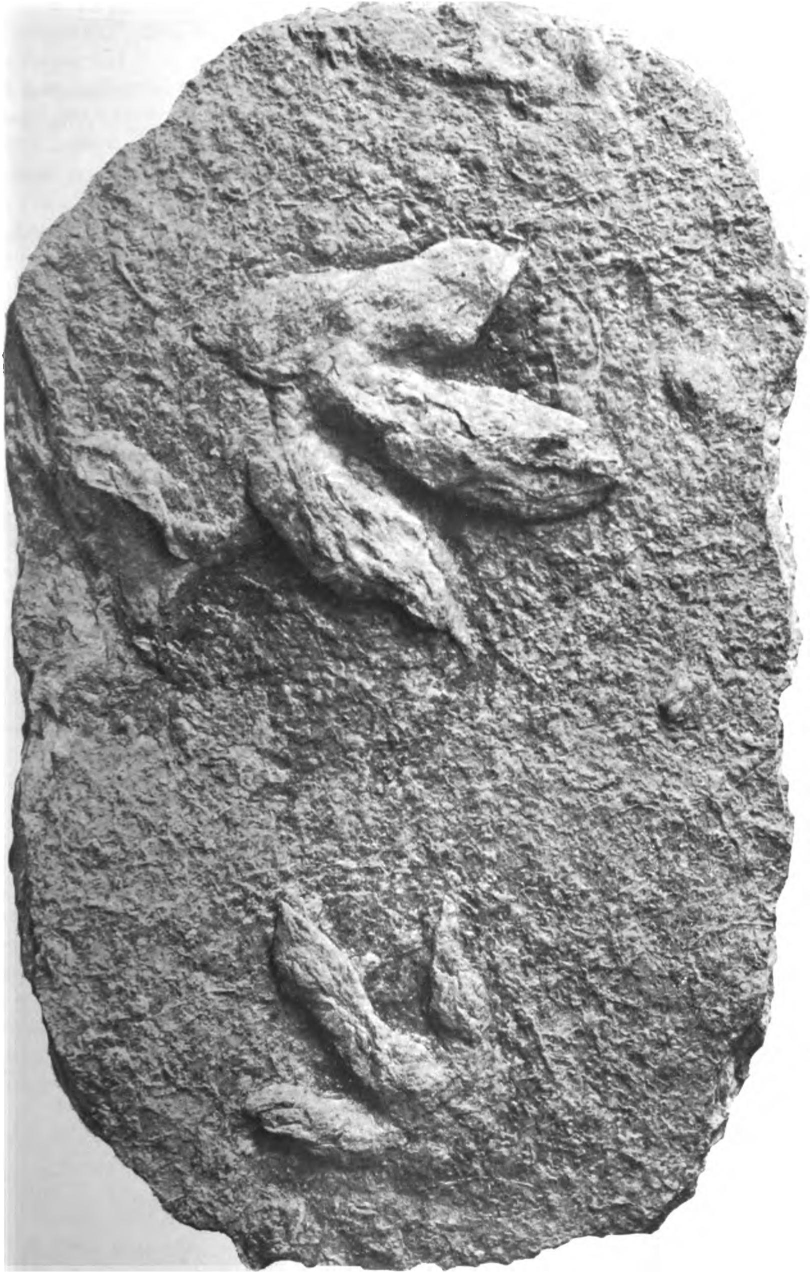
The fossil footprints here described were found by H. F. Wells, in 1898, in the Atlantosaurus beds, on the southwestern border of the Black Hills in South Dakota. The specimens are now deposited in the Yale Museum.

Yale University, New Haven, Conn.,
February 21, 1899.

Explanation of Plate V.

Footprints of Jurassic Dinosaurs from the Black Hills, South Dakota.
One-sixth natural size.

Plate V.

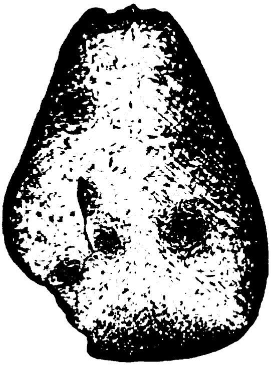


Footprints of Jurassic Dinosaur.

ART. XXIV. — *A new Kansas Meteorite;* by HENRY L. WARD, Rochester, N. Y.

IN October last Sam G. Sheaffer, Esq., Attorney-at-Law, of Ness City, Kansas, called our attention to a meteorite that he had in his possession; and which, after some correspondence, he sent to Ward's Natural Science Establishment for the purpose of disposing of it.

Mr. Sheaffer writes that "it was found about a year ago in the southwest of this, Ness County, Kansas. Was picked up on the side of a draw, i. e., a dry creek, where the surface had been eroded."



In form it is a triangular pyramid with the base set obliquely to its perpendicular.

A mass of some weight had long ago separated from the lower left hand corner, as seen in the figure; but whether before, upon, or after reaching the earth it is now impossible to determine from the fractured part. Several slight depressions appear on the surface, which are rather too sharply indicated in the accompanying figure. The edges of the nearly plane faces meet in rounded angles.

The meteorite is 92^{mm} in length, 64^{mm} across its widest face, left to right of figure, and 49^{mm} in thickness, measured perpendicularly to the widest, and also largest, face. The termination had been chipped away for the purpose of ascertaining its meteoric character before it was sent to us. The weight of the mass is 417 grams.

This is not a prepossessing meteorite. It entirely lacks the black crust characteristic of aerolites; and so strongly suggested a weathered marcasite concretion that we were at first skeptical as to its meteoric origin. However, tests for iron and for nickel were both affirmative, and a polished chip showed the former well distributed as minute specks through the mass. A complete analysis has not yet been made.

To our knowledge but one other meteorite has been described from Ness County, Kansas. That is the Kansada aerolite designated by the name of the town near which it was found. The locality whence came the specimen under consideration, Section 2, Township 20, S. of Range 21 west, is not marked by a town; and I therefore propose to designate this meteorite as the Ness County.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Density and Composition of Liquid Air.*—Experiments have been made by **Ladenburg** and **Krügel** on the densit of liquid air of varying composition. The method employed wa to weigh a glass rod, whose density at 4° was known, in th liquid air contained in a silvered Dewar bulb, by means of Mohr balance, and to calculate the density from the loss i weight. At the same time, the composition of the air was determined by Bunsen's method, suitably modified for the purpose In this way three estimations were made. In the first, th liquid air used was freshly prepared; in the second it had bee allowed to stand some time until a portion of the nitrogen ha volatilized; while in the third, it was not used until the second o third day after its preparation. The density of sample one wa found to be 0·9951, and its content of oxygen 53·83 per cent that of sample two was 1·029, and its oxygen 64·2 per cent that of sample three was 1·112 and its oxygen 93·6 per cent Three facts appear here for the first time: first, that liquid air i lighter than water; second, that the liquid air poorest in oxyge contains over 50 per cent of this element; and third, that th last portions, consisting of nearly pure oxygen, have a densit greater than that of liquid oxygen itself. Moreover the densit of the gas from this residue was found to be greater than that o gaseous oxygen; it being 1·125 while that of pure oxygen i 1·1056. This is due probably to an admixture either of carbo dioxide or possibly of krypton. From these data the density o ordinary atmospheric air containing 20 per cent of oxygen, an which is not yet obtainable in the liquid state as such, should b calculable, either by geometric or algebraic methods. If the content of oxygen be plotted as abscissas and the density as ordinates, three points are obtained lying nearly in a straight line Prolonging the line connecting either two of these points till i cuts the ordinate drawn through 20·9 per cent oxygen, values fo the density are obtained lying between 0·887 and 0·908. For ai free from oxygen, i. e., for pure nitrogen, a value of about 0·84 i obtained, Olszewski having obtained 0·85. Or analytically, assuming that the three points lie on a curve of the second degre such as $y = a + bx + cx^2$, the constants a, b and c can be calculated from the experimental values of y the density, and x th oxygen-content, above given. So that the equation becomes

$$y = 0{\cdot}77892 + 0{\cdot}00463x - 0{\cdot}0000115x^2.$$

For the value $x = 20{\cdot}9$ per cent of oxygen, this equation gives a the value of y, the density, 0·8707. Hence were it possible t liquefy atmospheric air without the more rapid evaporation of th nitrogen, it would have a density between 0·87 and 0·90. Th authors have applied the same method to the determination of th density of liquid oxygen and of ethylene. Both gases were liquefied in U-tubes immersed in liquid air. Two experiments with different glass rods, gave for oxygen at the boiling point of liquid air (between −183° and −188°) a density of 1·105–1·108; these values becoming 1·110 and 1·113 when the correction for the change in volume of the glass is applied. Olszewski's value at −181·4°, the boiling point of oxygen, was somewhat higher, 1·110 to 1·137. On passing ethylene gas into a tube immersed in liquid air in a Dewar globe a crystalline mass of solid ethylene is at once obtained, whose melting point was found to be −169°, and its boiling point −105·4° at 760^{mm} pressure. The density of the liquid ethylene at −169° was found to be 0·6585 and at −105·4°, 0·5710. Methane made from sodium acetate and barium oxide gave variable results, probably from the presence of hydrogen and perhaps of ethylene.—*Ber. Berl. Chem. Ges.*, xxxii, 46, January, 1899. G. F. B.

2. *On Semi-Permeable Membranes.*—Experiments which have been made by MIJERS have led him to differ from the opinion of Ostwald that semi-permeable membranes are not only conductors like metals but are also "ion sieves." He calls attention to the fact that the copper which is deposited on semi-permeable membranes possesses the nature of a spongy mass rather than a coherent one. If a glass cylinder be closed by a membrane of copper ferrocyanide on parchment paper, and be filled with normal solution of copper sulphate, and then placed in an electrolyzing vessel containing the same solution, the current from two Bunsen cells being passed through it, it is found that no copper is deposited on the membrane during the first half hour, a deposit taking place only when the liquid in the cylinder has become nearly colorless. On weighing the cathode, which is placed in the cylinder closed by the membrane, both before and after the experiment, it is observed that the amount of the deposited copper is in excess, by a considerable amount, of that which was previously contained in the solution in the cylinder, showing that copper must have passed through the membrane. Placing a platinum cathode in acidulated water in a similar cylinder closed by a membrane, and putting this in an electrolytic vessel containing copper sulphate solution, metallic copper is deposited in a few minutes on the cathode; and after four hours the amount of this copper is more than a hundred times that contained in the precipitated copper ferrocyanide on the membrane, which retains its color and is not acted on by the acid. The author's experiments seem to show that semi-permeable membranes are conductors differing entirely from metals. Thus if, in a copper sulphate electrolyzing vessel the anode and cathode are separated by a semi-permeable membrane held between two rings of ebonite, and by a sheet of platinum of exactly the same size as the membrane, no metal is deposited on the membrane when the current passes, the deposit taking place on the platinum near the center, the margin being protected by the ebonite.—*Rev. Trav. Chim.*, xvii, 177, 1898; *J. Chem. Soc.*, lxxiv (ii), 505, November, 1898.

G. F. B.

3. *On the Solution of Platinum and Gold in Electrolytes.*—It has been observed by MARGUELES that if an electro-magnet provided with a vibrating armature be made to act as a contact breaker to the current from two Daniell cells, an electrolytic cell provided with platinum or gold electrodes being included in the circuit, the metal can be made to dissolve in hydrochloric, nitric or sulphuric acid, or in potassium or sodium hydrate. The solution always takes place from that electrode which is for the time being the anode. It is helped in some way, however, by the discharge current from the magnet, as the current from the battery alone does not effect the solution, neither when continuous nor intermittent.—*Wied. Ann.*, lxv, 629–634, June, 1898. G. F. B.

4. *Aqueous Solutions of Metallic Gold.*—By treating a feebly alkaline boiling solution of gold chloride with a reducing agent, ZSIGMONDY has shown that a red aqueous solution of metallic gold may be obtained.* Formaldehyde seems to be the best reducing agent, less satisfactory results being given by acetaldehyde, alcohol and hydroxylamine. Sometimes the solution, instead of being red, is dark purple, violet or bluish black and appears turbid. The solutions of gold are very dilute, only about 0·005 gram of gold to the hundred cubic centimeters. They undergo no change when boiled until reduced to less than half their volume, when they become violet-black and deposit gold as a black powder. The solutions may be concentrated by dialysis, which become intensely red and contain 0·12 per cent of colloidal gold. Solutions of neutral salts and mineral acids change the color to blue and slowly precipitate finely divided metallic gold. Potassium ferrocyanide produces a green coloration, subsequently becoming yellow. Acetic acid gives a violet red and finally a black. Alkalies precipitate blue gold. Alcohol in excess changes the color gradually to dark violet, precipitating the metal completely in a condition in which it is soluble in water. When submitted to the action of a current, aqueous solutions of gold act like other colloids; the metal travels toward the cathode, but does not penetrate the membrane.—*Liebig's Annalen*, ccci, 29–54, June, 1898. G. F. B.

5. *On the Explosion of Mixtures of Methane and Air by the Electric Current.*—Extended experiments have been made by COURIOT and MEUNIER on the action first of incandescent wires and second of electric sparks, on mixtures of methane with air in various proportions, the gas being sometimes at rest and sometimes in motion. A mixture of 80 per cent of methane and 20 per cent of air, in motion, could not be fired by an incandescent wire nor even by the spark at the break when the wire fused; though it readily ignited in contact with a flame. If an electric current produces any effect at all on a mixture of methane and air, the only effect is an explosion. But under no circumstances were the authors able to produce an explosion with an incandescent wire. Whenever an explosion was produced it was due to the spark produced at the breaking of the wire. A mixture con-

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* See Faraday's Exp. Res. in Chem. and Phys., p. 411.

taining 9·5 per cent of methane is the most readily explosive. The combustion is complete so long as the methane does not fall below 5·5 per cent. Even with 4·5 per cent slight explosions were noticed. With 12 per cent of methane, the explosibility reaches its maximum limit, no explosion having ever been obtained when the proportion was as high as 12·25 per cent.

In a subsequent paper, the authors state that if the current by which the wire is heated be shunted with a parallel wire, the production of the spark causes no ignition of the gas, if the resistances are equal in the two branches. If the shunt-resistance is high, or on the other hand if this resistance falls below a certain value, the production of a spark always produces an explosion. To avoid an explosion therefore the current strength must not exceed a certain maximum depending on the resistance of the two branches of the conductor.—*C. R.*, cxxvi, 750, 901, March, 1898.

G. F. B.

6. *On a Crystallized Compound of Cuprous Chloride and Acetylene.*—It has been pointed out by CHAVASTELON that on treating cuprous acetylide with hydrochloric acid in the cold, an appreciable evolution of gas takes place; due probably to the decomposition on warming of a compound of cuprous chloride and acetylene. Further investigation showed that this compound may be prepared either by the action of acetylene on a solution of cupric chloride in alcohol or in water, in presence of metallic copper, or by passing this gas into a saturated solution of cuprous chloride in dilute hydrochloric acid, at a temperature at or below 12°. By the latter method, which is preferable, large hexagonal crystals are obtained belonging to the orthorhombic system, having the composition $C_2H_2 : Cu_2Cl_2$. By the former process, silky crystals are yielded, which are liable to contamination by a violet-purple deposit, formed early in the reaction. Both products alter readily on exposure to the air, and are at once decomposed by water or by solutions of alkali chlorides, with evolution of acetylene and the production of the above mentioned violet-purple substance. The crystals dissociate on warming without explosion, producing at 78° a pressure of 262^{cm}.—*C. R.*, cxxvi, 1810–1812, June, 1898. G. F. B.

7. ***Matter, Energy, Force and Work.*** A plain presentation of Fundamental Physical Concepts and of the Vortex-atom and other Theories. By SILAS W. HOLMAN, Professor of Physics (Emeritus) Mass. Institute of Technology. 12mo, pp. xiv, 257. New York, 1898 (The Macmillan Co.).—The aim of this book, as the preface tells us, is to present some fundamental ideas and definitions of physics in a plain and logical manner. The subject matter proper is contained in the first part, the definitions and views there given constituting "a sporadic attempt at clear consecutive setting forth of individual thought." The second part consists of speculations on matter and energy. Two new terms are introduced, ***kinergety*** and ***weightal.*** Kinergety in the abstract sense denotes "the idea of capacity for kinetic energy" and in the concrete sense "the quantity of this capacity." Weightal is

defined to be "quantity of substance measured by the equal-arm balance." With regard to the vortex-atom theory, Lord Kelvin writes to the author "I am afraid it is not possible to explain all the properties of matter by the vortex-atom theory alone." "I have not found it helpful in respect to crystalline configurations, or electrical, chemical or gravitational forces." The book contains a thoughtful presentation of fundamental physical concepts and cannot fail to be of much service to those students who desire a philosophic knowledge of modern theories. G. F. B.

8. *Uranium Radiation, and the Electrical Conduction produced by it.*—A very exhaustive investigation of this subject has been published by Prof. RUTHERFORD of McGill University. Becquerel had stated that the uranium rays differed from the Röntgen rays in this respect, that they can be refracted and polarized. Professor Rutherford cannot find any evidence of refraction or polarization. The theory of ionization adopted by the author supposes that the rays in passing through a gas produce positively and negatively charged particles and that the number produced per second depends on the intensity of the radiation and the pressure. The term ion does not assume that the ion is necessarily of atomic dimensions. These ions are supposed to be carriers of electricity. Prof. Rutherford examines the theory that energy is absorbed in producing the ions and that the absorption is proportional to the number of ions produced and thus depends on the pressure. If this theory is correct he points out that we should obtain the following results:

(1) Charged carriers produced through the volumes of the gas.

(2) Ionization proportional to the intensity of the radiation and the pressure.

(3) Absorption of radiation proportional to pressure.

(4) Existence of saturation current.

(5) Rate of recombination of the ions proportional to the square of the number present.

(6) Partial separation of positive and negative ions.

(7) Disturbance of potential gradient under certain conditions between two plates exposed to the radiation.

The experiments performed by the author indicate that the theory affords a satisfactory explanation of the electrical conductivity produced by uranium radiation. He shows also that the uranium radiation is complex, and that there are present at least two types, which he terms α- and β-radiations. The character of the β-radiation seems to be independent of the nature of the filter through which it has passed, and passes through all substances tried with far greater facility than the α radiations. The photographic effects are due principally to the β-radiations, except when the uranium compounds are placed close to the photographic plate. The experiments on transparency of metallic plates are not in accordance with those of Becquerel. The absorption of the β-radiation in gases is probably of the same order as that of the X-rays.—*Phil. Mag.*, January, 1899, pp. 109–163. J. T.

9. *On the Silver Voltameter and its use in determinations of normal elements.*—In a contribution from the Reichsanstalt, K. **Kahle** discusses the subject and gives the results of a careful inquiry of the electromotive force of a Clark and a Cadmium cell, and a comparison with previously obtained results by means of a Helmholtz electrodynamometer (Wied. Ann., lix, p. 532, 1896) of the electrochemical equivalent of silver. The final value obtained is E = 1·1183 mg / sec. which is in accordance with the previously obtained value.— *Wied. Ann.*, No. 1, pp. 1–36, 1899.

J. T.

10. *Absorption of light by a body placed in the magnetic field.*—**Rhigi** discusses the work of investigators who have occupied themselves with the phenomena of absorption discovered by him. It is shown that the Zeeman effect is accompanied by a rotation of vibrations of which the wave lengths are close to those of the radiations absorbed. According to Becquerel and Voigt, one could predict this rotation from the facts of anomalous dispersion. Rhigi does not believe with MM. Corbino and Macaluso that the rotation constitutes the principal cause of the appearance of light in his experiments; for the condition that the phenomena of rotation may be observable, namely, great length of rays of absorption, is not necessary and is even prejudicial. One cannot maintain absolutely that Rhigi's experiments would lead to the discovery of the Zeeman effect. They reveal the existence of a phenomenon less simple—a Zeeman effect together with rotations, more or less simple, of vibrations which, it may be, always accompany it.— *Comptes Rendus*, No. 1, pp. 45–48, January, 1899.

J. T.

II. GEOLOGY AND MINERALOGY.

1. *Recent Earth Movement in the Great Lakes Region;* by **Grove Karl Gilbert**. (From the Eighteenth Annual Report of the Survey, 1896–97. Part II.)—The question as to the existence at the present time of progressive changes of level between the water and land in the region of the Great Lakes is one not only of great theoretic interest, but also of much practical importance, since a relative rise of the water may have a profound effect upon the value of property on the shores of the Lakes. This subject is discussed by Mr. Gilbert with great care and thoroughness. He remarks upon the earth movements which characterized the closing epochs of the Pleistocene Period, as clearly brought out by the studies of Dr. Spencer, Mr. F. P. Taylor, and others, of the shore lines of the early glacial lakes that covered more or less of the region. He quotes Dr. Spencer (1894) as urging that this change of level has not ceased, and that it will eventually turn the water of the Upper Lakes southward to the Illinois and Mississippi Rivers, leaving the Niagara channel dry. This is one consideration which has weight in the matter.

Another is found in the condition of the estuaries which show

a close resemblance to features observed along the subsidin
parts of the Atlantic coast, and give an impression that a slo
flooding of the stream valleys is still in progress. A third poin
noted is the accepted fact that the Atlantic coast, south of Connecticut, is subsiding, as has been estimated (Cook) for New Je
sey about two feet in a century; while the land about Hudson an
James bays has risen (Bell) perhaps five to seven feet in a cen
tury. These facts all point in a common direction, warranting th
hypothesis that the tilting of the Lake region which went on a
the close of the glacial times, as shown by the slopes of old shor
lines, is still in progress.

The author notes at the outset a paper by Mr. G. R. Stunt
(1869), in which he argued, in the case of Lake Superior, tha
there was a gradual rise of water at the west end of the lake, an
a fall of the same at the east, referring this to a westward cantin
of the basin, the western part becoming lower as compared wit
the eastern.

With this introduction the author goes forward to discuss th
plan of investigation, and the data available, with also certai
special observations made in 1896. The stations are taken i
pairs, the points being so chosen as to most satisfactorily sho
what change of level, if any, has been going on. An absolut
conclusion is difficult to reach, since very few of the observation
are above question because of the doubt as to the stability of th
individual base levels involved. Still the candor and fairnes
with which the author weighs the evidence is worthy of all prais
and gives his conclusions great value.

He decides that the harmony of the measurements, and thei
agreement with the predictions of geological data, makes s
strong a case for the hypothesis of tilting that it should b
accepted as a fact, although some doubts exist concerning th
stability of the gauges. The mean rate of change deduced i
0·42 foot to one hundred miles in a century; but this depend
upon certain assumptions which he does not regard as altogethe
probable, and he notes that the change indicated by Stuntz
observations is much more rapid. It would seem then that th
assumption is justified that the whole Lake region is being lifte
on one side or depressed on the other, so that its plane is bodil
canting toward the south-southwest, and that its rate of chang
is such that the two ends of a line one hundred miles long, an
lying in a south-southwest direction, are relatively displaced fou
tenths of a foot in one hundred years. Certain general cons
quences follow from this assumption (eliminating irregularitie
due to difference of rainfall, evaporation, etc.). Thus, on Lak
Ontario, the water is advancing on all the shores. This is als
true of Lake Erie, the most rapid change, of eight or nine inche
in a century, being at Toledo and Sandusky. About Lake Huro
the water is falling more rapidly in the north and northeast. A
Lake Superior the water is advancing on the American shore an
sinking on the Canadian. Similar relations exist for Lake Mich

gan, the water falling in the north and rising in the south, at Chicago some nine or ten inches. The ultimate result would be the discharge of the lakes through the Illinois river, the channel of the Pleistocene glacial lake being occupied anew. The high-water lake discharge may begin in 500 to 600 years, for mean lake stage it will begin in 1,000 and after 1,500 it will go on uninterruptedly. In about 2,000 years the Illinois river and Niagara will carry equal portions of the surplus water of the Great Lakes, and in 3,500 there will be no Niagara. The author adds: "The most numerous economic bearings of this geographic change pertain to engineering works, especially for the preservation of harbors and regulation of water levels. But the modifications thus produced are so slow as compared to the growing demands of commerce for depth of water that they may have small importance. It is a matter of greater moment that cities and towns built on lowlands about Lakes Ontario, Erie, Michigan, and Superior will sooner or later feel the encroachment of the advancing water, and it is peculiarly unfortunate that Chicago, the largest city on the lakes, stands on a sinking plain that is now but little above the high-water level of Lake Michigan."

The paper closes with a statement of certain definite plans made for precise measurements at selected stations, for example, at Chicago, Port Huron, Parry Sound, and Mackinaw, which if they can be carried out systematically, must in time lead to a very definite solution of the problem in hand.

2. *On the Petrology of Rockall Island.*—Professor J. W. JUDD has recently described a remarkable rock under the name *rockallite* from the isolated point which rises from a shoal above the waves of the North Atlantic 240 miles west of Ireland. It appears to be a remnant of an intrusive sheet resting on sediments. The tiny islet has long been known under the name of Rockall. Prof. Judd's paper forms one of a series of memoirs descriptive of this remarkable island.* As this rock is of very interesting character a brief description will be of interest to petrographers.

It is of granitic character but with an approach to a porphyritic structure in places owing to the idiomorphic outlines of the lath-shaped feldspars, which allies it to the granite porphyries. In composition it is very simple, being made up of ægirite, albite and quartz in the following proportions: ægirite 39, quartz 38, albite 23.

The ægirite is found in larger crystals and in fine needles, and shows at times brown acmite zones. The albite is twinned according to the albite and Carlsbad laws and its phenocrystic sections contain ægirite. The quartz is the last mineral to form and fills the interspaces. A little apatite and soda amphibole are present. The specific gravity varies from 2·9–2·7. In the more porphyritic variety a little groundmass is present. The chemical analysis gave these results:

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* Notes on Rockall Island and Bank with an account of the Petrology of Rockall, and of its winds, currents, etc.: with reports on the Ornithology, the Invertebrate Fauna of the Bank and on its previous history. Transactions of the Royal Irish Academy, vol. xxxi, Part III, pp 39–98, plates ix to xiv.

SiO_2	Al_2O_3	Fe_2O_3	MnO	NiO	MgO	CaO	Na_2O	K_2O	P_2O_5	
73·60	4·70	13·10	·93	·06	·11	·37	6·96	tr.	tr.	= 99·83

In this TiO_2 and FeO were not determined. The analysis is remarkable for the low alumina, the high iron and the absence of potash. In these respects it is most closely related to the grorudites of the south Norway region and to some of the lavas of Pantellaria. From them it differs however in its granitic structure, the higher proportion of ægirite and in the character of its feldspar. The introduction of its name as a varietal one in the alkaline granite group is therefore justified. L. V. P.

3. *Recherches géologiques et pétrographiques sur le massif du Mont Blanc;* by L. Duparc et L. Mrazec (Mem. Soc. de Phys. et Hist. Nat. de Genève, xxxiii, No. 1, 4°, pp. 227, pl. 33, 1898).—In this great work the first part is devoted to a full account of the topography of the Mont Blanc massif and the position it occupies in the system of the Alps. Then follows a very full petrographic investigation of the eruptive rocks and of the relations existing between them followed by a similar account of the crystalline schists which accompany them. A very large number of analyses of the types described is also given.

The fourth part is devoted principally to the description and theory of the metamorphic phenomena produced by the protogine in the crystalline schists with which it is in contact. The next part is a description of the sedimentary rocks involved in the mass and the whole concludes with a discussion of the tectonic processes and of the folds and uplift which they have produced. In addition to the large number of half-tone plates of scenery and rock sections, a number of excellent geologic sections in color are given. The authors regret that the expense prohibited an accompanying publication of the geologic map they have made, a regret in which all readers will agree with them.

The whole is an exhaustive monograph and gives the results of an enormous amount of painstaking labor both in the field and in the laboratory. It is one of the most important contributions to Alpine geology which has appeared in recent years. L. V. P.

4. *Native Silver in North Carolina;* by G. F. Kunz. (Communicated.)—In June, 1898, while some mining was being carried on at the West Prussian Mining Company's land, at Silver Hill, near Livingston, Davidson Co., N. C., an interesting deposit of native silver was brought to light. An inclined shaft was sunk to a depth of 75 ft., near a mixed mass of sulphides of lead, zinc, copper and iron, associated with a vein of green rock, in places weathered and decomposed almost to a white clay. In and through this, a soft, slaty mass of native silver was found, disseminated in grains and plates presenting the appearance of having been absorbed in the interstices of the slate, and varying in size from minute grains and scales of metal to pieces several

square inches in area, and up to one-fourth of an inch in thickness; the largest single mass weighing, with some of the adherent slate, about 5 lbs.

The sulphides are not crystallized; but appear to be almost homogeneous and are comparatively rich in lead and zinc, an average assay yielding 35 per cent of zinc and 20 per cent of lead, with 25 ounces of silver and one-fourth an ounce of gold to the ton. An assay made by Dr. A. R. Ledoux proves the silver to be almost absolutely pure, containing only 1 per cent of native gold. The silver occurs in veins, with more or less open spaces, and showing very minute crystals on the upper and lower part of the vein. A near view, side-ways, reveals it to be in fibrous masses and ropes, having all the appearance of sweating out of the rock, probably a result of the decomposition of the chloride, leaving the silver in fine, fibrous masses, varying from short ropes 10 millimeters in diameter to the fineness of a hair.

The specimens and information were kindly furnished by Wyndham H. Wynne, of Glendalough, Ireland.

5. *On the occurrence of polycrase in Canada;* by G. Chr. Hoffmann. (Communicated.)—Fine examples, of what on examination by Mr. R. A. A. Johnston proved to be polycrase, have been found by Mr. C. W. Willimott, in the township of Calvin, district of Nipissing, in the province of Ontario. It occurs here in the form of crystalline masses—one of which weighed rather more than seven hundred grams—associated with xenotime, a highly altered, cleavable massive form of magnetite, and small quantities of a brownish-red spessartite, in a coarse granite vein, composed of quartz, microcline, albite or oligoclase, muscovite and biotite, which is there found cutting a reddish, fine-grained, hornblendic gneiss. The mineral has a pitch-black colour; an uneven, in parts subconchoidal fracture; a resinous lustre; is brittle; and affords a grayish-brown streak. Its specific gravity, at 15·5° C., is 4·842. A very carefully conducted qualitative analysis showed it to contain—Niobic oxide, large amount; tantalic oxide, somewhat small amount; titanic oxide, large amount; yttrium oxide, somewhat small amount; thorium oxide, small amount; stannic oxide, trace; cerous oxide, small amount; lanthanum oxide, small amount; didymium oxide, small amount; uranous oxide, small amount; ferrous oxide, small amount; magnesia, trace; water, very small amount. Zirconia was sought for, and found to be absent.

6. *The Kaolins and Fire Clays of Europe, and the Clay-working Industry of the United States in* 1897; by Heinrich Ries. From the Nineteenth Annual Report of the U. S. Geological Survey, 1897–1898.—Professor Ries has here brought together a large amount of important information on the occurrence, composition and general use of the clays from the important localities in Europe. This is chiefly based upon the personal observations of the author during recent visits to the localities themselves. The value of the paper will be appreciated when the importance

of the industry in this country is considered, and at the same tim the very imperfect and fragmentary amount of information whic has already been published in the various technical journals. A brief summary is also given of the clay industry in the Unite States.

7. *On the Origin of the Gases evolved on heated Mineral Substances, Meteorites, etc.*—A paper by M. W. TRAVERS in th Proceedings of the Royal Society (No. 405) discusses the evolution of gases from various minerals and meteorites, especiall with reference to their origin. His conclusions are somewhat a variance with those ordinarily accepted, in that the experiment go to prove that in the majority of cases, the gas evolved unde the influence of heat is the product of decomposition or interaction of non-gaseous constituents present in the substance unde examination. It is conceded that compact minerals do inclos carbon dioxide and hydrocarbons as easily liquefiable gases; bu the analogy cannot be extended to gases such as hydrogen an helium in connection with readily cleavable minerals like chlorit mica and cleveite. The special importance of the conclusions her reached lies in the fact that it invalidates the conclusion reache in regard to the origin and history of the substances in questio This is partly true in the case of meteorites.

III. BOTANY AND ZOOLOGY.

1. *Symbolæ Antillanæ seu Fundamenta Floræ Indiæ Occidentalis;* editit IGNATIUS URBAN. Vol. I, Fasc. I continet: I, Ig Urban: Bibliographia Indiæ occidentalis botanica, pp. 3–19 Berolini, 1898 (Fratres Borntraeger).—Within recent years, Professor Urban has published numerous papers dealing with th flora of the West Indies. His articles have appeared in variou German journals and have of necessity been somewhat scattere and disconnected. It is now his intention to publish the furthe results of his studies in this domain in a series of papers unde the above title, the various fasciculi to appear at indefinite perio and to deal mainly with difficult or neglected families, the description of new genera and species and the geographical distributio of plants on the islands. This first paper contains a list, arrange alphabetically according to authors, of the numerous works dealing with the botany of the West Indies, but it is much more tha a mere enumeration. After each title, which is given in full an also in a shortened form suitable for citation, follows an abstrac of its contents, and, in the case of taxonomic papers, an indication as to where the plants described are at present preserve Especially valuable are the many references to works publishe in Spain or in the West Indies themselves, many of which ar difficult of access and therefore little known to botanists.

A. W. E.

2. *Plant life: considered with special reference to form an function;* by CHARLES REID BARNES, Professor of Plant Phys

ology in the University of Chicago; pp. x + 428, with 415 figures in text. New York, 1898 (Henry Holt & Company).—As stated in the preface, Professor Barnes' text-book attempts "to exhibit the variety and progressive complexity of the vegetative body; to discuss the more important functions; to explain the unity of plan in both the structure and action of the reproductive organs; and finally to give an outline of the more striking ways in which plants adapt themselves to the world about them." The four parts into which it is divided deal accordingly with the following subjects: I. The Plant Body; II. Physiology; III. Reproduction; and IV. Ecology. It will be seen, therefore, that the book is very comprehensive in its plan and that most of the great divisions of modern botany receive a certain amount of attention. The topics are, with few exceptions, treated according to recent researches, but the very comprehensiveness of the subject makes great conciseness necessary, and it is to be feared that some of the statements are so concise as to be obscure, at least to pupils from thirteen to eighteen years of age, for whom the book is primarily intended. The arrangement of the subject-matter, also, although logical, might readily lead the pupil to believe that a plant is composed of certain definite and more or less disconnected parts, instead of being an organism whose parts, although distinct enough from a formal standpoint, are nevertheless so intimately connected and so dependent upon one another that they form a most definite whole: in other words, that botany is the study of plant-organs rather than of plants. For example, under "simple sporangia" on page 316, the sporangium of Mucor, the ascus of Peziza and the tetrasporangium of Polysiphonia are described in due order; but, if we wish to find other facts about Polysiphonia, we must look on page 32, for a description and figures of the vegetative structure, and on page 280, for a figure of the cystocarp: and other, even more striking examples might be quoted. The short section on ecology, which, as the author implies, is largely abridged from two recent German works, is an interesting feature of the book, and, it is to be hoped, will demonstrate to teachers how very useful this important department of botany might become for purposes of instruction. At the close of the book are five appendixes in which laboratory directions, lists of apparatus, reagents and reference books, and a very brief outline of classification are given. A. W. E.

3. *Rhodora: Journal of the New England Botanical Club*, Vol. I, Nos. 1 and 2, January and February, 1899. Boston and Providence.—After mature consideration, the New England Botanical Club has decided to publish a journal devoted to the interests of New England botany. The first two numbers have recently appeared, and the editorial announcement states that the journal will devote special attention to matters connected with the geographical distribution of New England plants and to the revision of difficult or misunderstood groups of species. It also states that "not only flowering plants, but ferns, mosses and

thallophytes will receive their proportionate share of attention." Some idea of the character of the matter presented may be obtained from the following titles, selected from the numbers before us: rattlesnake plantains of New England (with plate); notes on algæ; a new wild lettuce from Massachusetts (with plate); notes on some fleshy fungi found near Boston; some plants about Williamstown; fairy-rings formed by Lycopodium; bryophyte flora of Maine. A. W. E.

4. *Catalogue of the Lepidoptera Phalænæ in the British Museum, Vol. I, Syntomidæ*; by GEORGE F. HAMPSON. With 17 colored plates. 8vo. London, 1898.—This is the first volume of a proposed catalogue of all the known genera and species of moths. The introduction contains a brief statement of the external structure of the Lepidoptera and an analytical key to the families. This is followed by the account of the Syntomidæ, a family of very pretty moths which is confined almost exclusively to tropical and subtropical regions. Nearly twelve hundred species are described and the genera and subgenera illustrated by 285 figures in the text. The plates contain about 370 beautifully colored illustrations of new or hitherto inadequately figured species, but, as they are not essential to the plan of the work, they are issued separately, so that the text may be sold at a much less price than if the plates were combined with it.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30th, 1898.*—The annual reports of the working of the Smithsonian Institution are always of much interest, because of its remarkably wide range of activity. One of its most important functions is the international exchange service, and the map of the world here introduced, which shows the distribution of its correspondents, sets forth in a very telling manner the perfection to which this system has been carried. Not only are correspondents very numerous in the well-known countries, but we find, for example, 99 in China, 204 in Brazil, 24 in Iceland, etc. The total number of correspondents is very nearly 30,000.

Much of interest is given in regard to the workings of the Smithsonian in every direction, but we can only speak particularly of the Astrophysical Observatory. Mr. C. G. Abbott, in charge, enumerates as follows the most important features of the work of the past year:

1. The instrumental equipment has received valuable accessions, including a highly sensitive galvanometer, designed and constructed at the Observatory; two cylindric mirrors by Brashear (which, as used for collimation of the spectroscope, are equivalent to a lens of 64 meters focal length), and, finally and most important of all, a system of cooling by the expansion of ammonia, which has made possible an extension of constant temperature

conditions to cover the five months of March, April, May, September, and October, otherwise frequently too warm. At present the change of temperature of the inner room between these warmer and the coldest winter months is only a fraction of a degree centigrade, and during an hour's observation it is generally less than one-tenth degree, the control being automatic.

2. Many bolographs of the infra-red solar spectrum have been taken, which, in consequence of these improvements, have yielded results threefold richer in "real" detail corresponding to solar and telluric absorption lines than any hitherto obtained.

3. About 40 of these bolographs have been compared, as described in the Appendix to the Secretary's Report for 1896, and 21 of the most perfect have been measured upon the comparator to determine the positions of the deflections found to be "real," or, in other words, corresponding to either solar or telluric absorption lines. These comparator measurements included about 44,000 separate observations.

There have thus been found over 700 absorption lines in the infra-red solar spectrum between wave-lengths 0·76 μ and 6·0 μ, an increase of about 500 over last year's results.

4. With the purpose of making a more accurate determination of the wave-lengths corresponding to the well-determined positions of the absorption lines discovered in the rock-salt prismatic spectrum, a very exact comparison of the dispersion of rock salt and fluorite has been made. This comparison will allow the indirect employment of certain recent and apparently very accurate determinations of the wave-lengths in the fluorite prismatic spectrum. Apparatus has been made ready and certain preliminary observations have been taken to directly measure the dispersion of rock salt. It is hoped that these steps will result in furnishing the wave-lengths of the infra-red absorption lines to a degree of accuracy corresponding to the exactness of the determination of their prismatic deviations.

5. Many interesting instances of local variations in the absorption have been noticed. Among these by far the most striking is a great decrease in the absorption at the longer wave-length side of the great band ψ at about 1·4 μ. This change occurred about February 15, 1898, and caused the bolographs to take on quite a different form at the place in question. This new form continued through the months of March and April, but in the month of May the usual form was gradually restored. It is found, by reference to former bolographs, that this marked decrease in absorption at this point takes place annually at about the same period, which coincides (fortuitously or otherwise) very nearly with that at which there is the greatest activity of growth in the vegetable kingdom. This raises the question whether the growth of vegetation does not abstract from the air great quantities of some selectively absorbing vapor active in absorption at this wave-length.

Whether such be the case or not future investigation must determine, but enough variations in the absorption have been observed to indicate that the Observatory is now in condition to make advances along the line indicated in the Secretary's Report for 1892, in which is pointed out the important relations of astrophysics to meteorology.

2. *Physical Geography;* by WILLIAM MORRIS DAVIS; pp. xviii, 428, with nine plates, etc. Boston, 1899 (Ginn & Co.).—This volume has the necessary elements of a high grade text-book: it is scientifically accurate, contains no unnecessary matter and is written in a pleasing manner. The earth's features are not only described, they are explained, and the reader is led to see a rational meaning in the varied land-forms about him. The student is constantly reminded, also, of the way in which physical features and climate have influenced man in his settlements, industries and manner of life.

The illustrations deserve special praise both in their selection and mechanical execution. The numerous "block-diagrams" are particularly valuable. Education in general and the out-of-door sciences in particular will be benefited by the introduction of just such text-books into secondary schools. H. E. G.

3. *The Annual Report of the Director of the Field Columbian Museum* to the Board of Trustees, for 1897–98. Report Series, Volume I, No. 4. Chicago, October, 1898.—This Report gives an interesting summary of the work of the Field Columbian Museum for 1897 and 1898. The numerous illustrations introduced give views of many of the rooms with their collections, and also of some of the objects of particular importance.

OBITUARY.

Prof. LOUIS W. PECK, for several years of the department of Physics in the University of Minnesota, died in Tucson, Arizona, on December 26th, in the 47th year of his age. He was born in Providence, R. I., and was educated in the Mass. Institute of Technology. He also served an apprenticeship in the Harris Corliss Engine Works in Providence. Prof. Peck's contributions to science were made in the investigation of the flouring mill explosion that occurred in Minneapolis, Minn., May 2, 1878. The mills exploded and then burned. They were insured against loss by fire and it became a question of great importance whether fire caused the explosion or the explosion caused the fire. Prof. Peck contrived a simple apparatus by which he showed that flour and wheat dust, when mixed with air in suitable proportions, would explode with terrific force *if ignited with flame.* Glowing charcoal and white hot platinum wires would not ignite the mixture, hence the conclusion was inevitable, confirmed by collateral evidence, that the mills were on fire before they exploded. Prof. Peck's results were embodied in a paper which was published in the Popular Science Monthly, xiv, p. 159, and the London Journal of Science, xvi, p. 666. This paper was widely copied and reviewed. S. F. P.

OTHNIEL CHARLES MARSH

PROFESSOR OF PALEONTOLOGY IN YALE UNIVERSITY, VERTEBRATE PALEONTOLOGIST TO THE UNITED STATES GEOLOGICAL SURVEY, AND FOR MANY YEARS AN ASSOCIATE EDITOR OF THIS JOURNAL, DIED AT HIS HOME IN NEW HAVEN AFTER A BRIEF ILLNESS, ON MARCH 18, IN THE 68TH YEAR OF HIS AGE.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXV.—*Glacial Lakes Newberry, Warren and Dana, in Central New York*; by H. L. FAIRCHILD. (With Plate VI.)

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Introduction.

THE ice sheet of the last glacial epoch covered, during its greatest extent, all the area of the Great Lakes. When the receding front of the waning glacier had passed to northward of the southern boundary of the Laurentian basin, the glacial and meteoric waters were impounded between the ice front and the north-sloping land surface. These glacial lakes had their outlets southward across the divide, and they expanded northward as the barrier of ice receded. The local lakes were gradually united by draining of higher levels to lower, and ultimately these glacial waters became of vast extent, exceeding in breadth and depth any existing lakes. Their shorelines have been found at many localities and traced for great distances and the romantic history and relationship of the glacial waters have become in recent years the subject of a special body of earth-science literature.

During the later phase of the Laurentian glacial waters, Lake Warren invaded central New York from the west, and drew down to its level the local waters of the Finger Lakes valleys. This region is of special interest, on account of its singular topographic character, and because it includes the critical locality where the great Warren waters found lower escape to the sea (than by the westward outlet to the Mississippi) and excavated in their flow toward the Mohawk a series of remarkable channels, piling the debris in great deltas in the more quiet waters of the intersected valleys.

The abandoned rock channels and correlating deltas are the most conspicuous features produced by the glacial waters. Southeast of Syracuse these great cuts in rock, some of them headed by cataracts, lie so close together that they cannot be represented satisfactorily upon the map (Plate VI). They are the last records of a lake history of truly dramatic interest. Their examination will repay not only the special student in geology and physiography, but the person having merely a general or casual interest in those sciences.

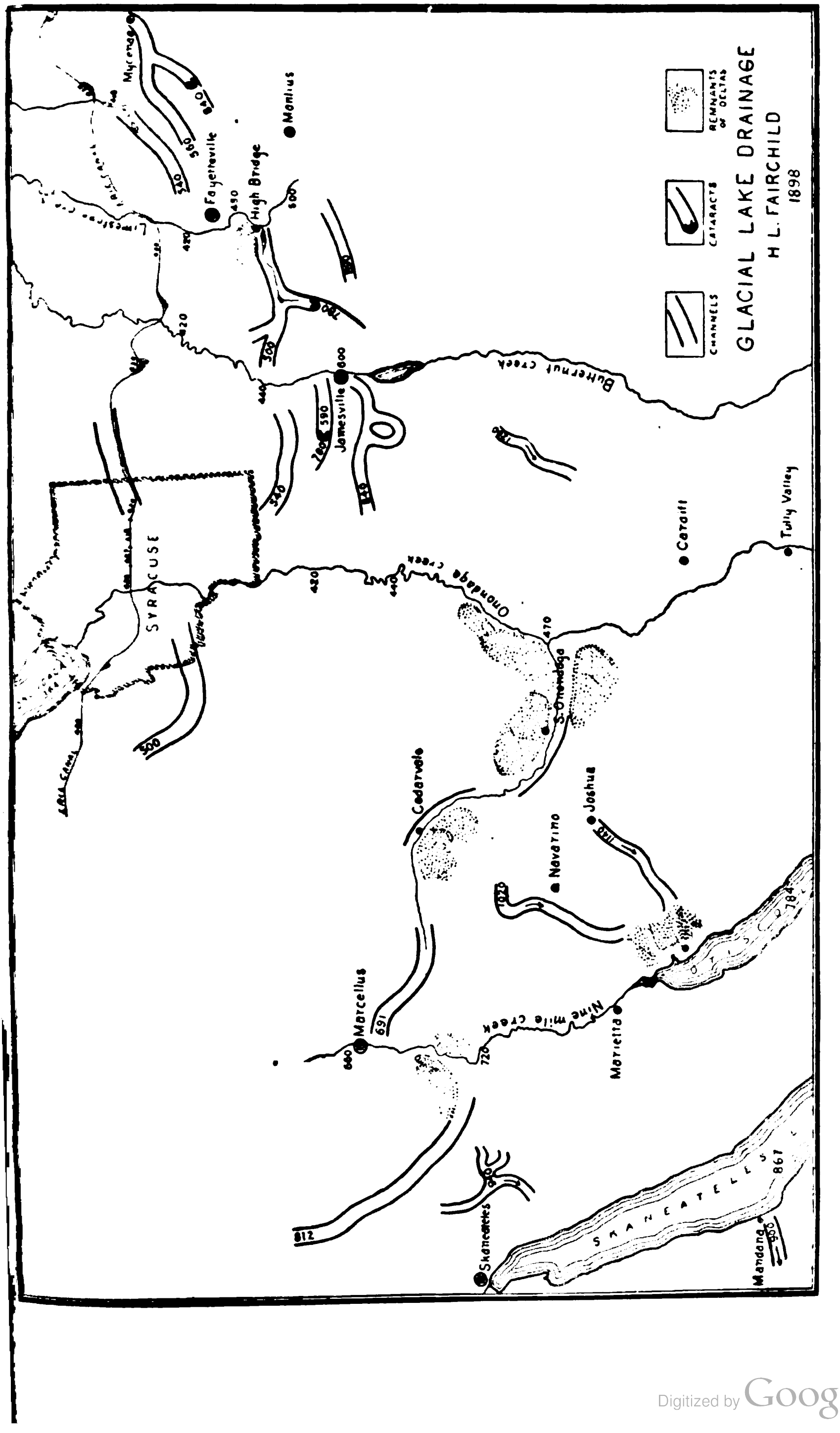
The study of the glacial lake phenomena in New York State has now been carried so far that the principal facts and relations in the history of those waters are known. It is the purpose of this writing to describe briefly the succession of events in the life and extinction of the later and broader glacial waters in the critical district of the Finger Lakes.

Description of the Maps, p. 251 and Plate VI.

The larger map locates in a generalized way the shorelines of the four greater glacial lakes, Newberry, Warren, Dana, and Iroquois.

The outlet of Lake Newberry was south to the Chemung River through the col (900 feet altitude) at the head of the Seneca Valley. The probable eastward limit of this water is indicated between Cayuga and Owasco Valleys, and the locality of its destructive drainage or lowering into Lake Warren is shown east of the north end of Canandaigua Lake.

The Warren waters found their first eastward escape southeast of Syracuse by either the channel west of Butternut Valley, with altitude 840 feet, or the one east of that valley with elevation 890 feet. (The channels are better shown on the smaller map.) The uncertainty as to the earliest spillway is indicated by the broken termination of the eastern end of the Warren shoreline. The most westerly of the hypo-Warren outlets is the one north of Skaneateles with elevation 812 feet. East of this channel is a series of channels which conveyed the overflow eastward to lower and lower levels.


GLACIAL LAKE DRAINAGE
H. L. FAIRCHILD
1898
CHANNELS
CATARACTS
REMNANTS OF DELTAS
Mycenae
840
560
540
Fayetteville
490
High Bridge
Manlius
800
420
700
500
Limestone creek
Erie Canal
Butternut creek
600
Jamesville
590
340
SYRACUSE
Onondaga creek
470
S. Onondaga
Cardiff
Tully Valley
Cedarvale
Navarino
Joshua
1020
1140
Otisco
784
Nine mile creek
Marietta
Marcellus
691
660
720
812
Skaneateles
SKANEATELES
867
Mandana
900

Lake Dana is a stage of the waters having their level determined by the outlet channel east of Marcellus, elevation 691 feet, with which the Dana shoreline terminates.

The several rock channels cut by the east-flowing waters in their escape to the Mohawk-Hudson lie so near together that they cannot be well represented on the larger map (Plate VI), but they are more clearly shown on the smaller map, p. 251.

The small circles on the larger map indicate cities or villages, the names of which are omitted to save confusion. On the smaller map the names are given.

The heavy broken line indicates the post-glacial divide between Laurentian and south-flowing waters. Bars drawn transverse to the water-parting indicate the location of outlets of the primitive local glacial lakes; those elsewhere on the map represent later outlets of secondary waters.

Numerals give elevations, in feet, above ocean level.

Physiography of the District.

The territory in general which includes the glacial lake phenomena described in this paper is that part of New York State known as the region of the "Finger" Lakes. Its more precise limitations are, on the west, the valley of Honeoye Lake and on the east a line somewhat beyond Syracuse. Those north and south valleys lying to the west of Honeoye, namely, Canadice, Conesus and the Genesee, were never related to the Newberry waters.

The accompanying map shows the hydrography of the present time. The topography will be sufficiently described, with the help of elevations given on the map, by stating that the area between Lake Ontario and the northern ends of the Finger Lakes is a plain of 400 to 600 feet elevation, while the north and south "Finger" Lake and intermediate valleys are preglacial trenches in an elevated tract of more enduring rocks. As far as the waning ice sheet upon the north left the land exposed, the northern and lower plain was covered by the Warren and Dana waters, which extended southward in a series of deep narrow bays up the valleys into the higher plateau. To the work of these lakes, with the subsequent Iroquois, is due the heavy silt deposits and the subdued topography of the lower part of this plain.

The ice movement, in the closing phase, followed the direction of the lake valleys, thus having a radial or spreading flow; and local lobes of the ice, or stream glaciers, protruded beyond the general ice front up each of the valleys, leaving in each valley a heavy moraine, which now constitutes the head of the present drainage, or the divide between north and south flow.

The ice was probably thicker in the deeper and broader valleys of Seneca and Cayuga, and the general direction of the retreating front of the great ice body was probably convex toward the south, and for our theoretical discussion may be regarded as normal to the axes of the divergent valleys.

Since the glacial lakes were drained the beaches have been thrown out of horizontal position by a differential northward uplift that has affected the entire Laurentian area. It is therefore evident that during the life of the glacial lakes the altitude of Central New York was much less than now, and that the depression was progressively greater toward the north or somewhat east of north.

Earlier Local Glacial Lakes.

As the front of the ice sheet melted back upon the north of the divide, the larger valleys in Central New York were occupied by important local lakes, which had their overflow across the divide into southern drainage. These lakes have been described with some detail in former papers by the writer.* For the present purpose it will be sufficient to enumerate the lakes and briefly state their location and relationship.

The glacial Honeoye occupied the valley of that name and sent its overflow into the Canandaigua Valley. At an earlier time the Honeoye Valley was flooded by the Canandaigua waters (Naples Lake).

The Naples Lake was the earliest glacial water in the Canandaigua Valley, with its outlet across the divide at the head of the valley, near Atlanta station. Subsequently a lower escape was found across the eastern border of the basin into the Flint Creek Valley and the waters became tributary to those in the Keuka Valley (Hammondsport Lake). This later phase of the Canandaigua waters is called the Naples-Middlesex Lake.

The Italy Lake occupied the upper Flint Creek Valley and overflowed at the head of the valley into Naples Lake. A lower stage of Flint Creek Valley waters, the Potter Lake, has not been fully studied at the time of this writing.

The Hammondsport Lake occupied the Keuka Valley. This valley had a lake history similar to that of the Canandaigua. The early phase of the Hammondsport Lake had its outlet south through Bath village. A later phase had its outlet across the eastern rim through the village of Wayne, but ultimately to the Cohocton Creek, like the earlier phase.

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*Glacial Lakes of Western New York, Bull. Geol. Soc. Amer., vol. vi, p. 353; Genesee Glacial Lakes, ibid., vol. vii, p. 423; Lake Warren Shorelines in Western New York and the Geneva Beach, ibid., vol. viii, p. 269; Glacial Waters in the Finger Lakes Region of New York, ibid., vol. x, p. 27–68.

The Watkins Lake occupied the upper Seneca Valley with outlet at Horseheads to the Chemung River. This was the predecessor of Lake Newberry, the latter being simply the former lake widely expanded into the Cayuga and other valleys adjacent to the Seneca Valley. (See page 255).

The Ithaca Lake occupied the Cayuga Valley with an outlet southeast to Catatonk Creek and the Susquehanna River.

The Groton and Moravia Lakes occupied the Owasco Valley, the former being the primitive lake in the main valley with outlet at Freeville, the latter being the later and larger lake with lower outlet southwest; both stages being tributary to the Cayuga waters.

The first glacial Skaneateles, in the valley of that name, overflowed by the head of the valley past Scott village and Homer to the Tioughnioga Creek, but a later and much lower stage, called the Mandana Lake (from the name of its outlet) received the overflow of glacial waters of the Otisco and Onondaga Valleys, and had its outlet westward into the Warren waters, which then occupied the Owasco Valley.

The glacial Otisco overflowed at first southward past Preble village to the Tioughnioga Creek, but a later stage of the waters, the Marietta Lake, had outlet westward into the lower stage of the Skaneateles. At the foot of this valley, and also of the Onondaga and Butternut Valleys, we find the great channels and deltas, produced by the eastward flow of Warren and later waters, which are to be discussed in this paper.

The Cardiff Lake occupied the upper Onondaga Valley and overflowed through the site of the Tully Lakes to the Tioughnioga Creek. A later, lower lake in the middle section of the Onondaga, the south Onondaga Lake, had its outlet by two successive channels westward to the Marietta Lake in the Otisco Valley.

Butternut Valley was long occupied by a primitive glacial lake, called the Butternut Lake, with outlet near Apulia station to the Tioughnioga Creek below Tully village. When the valley was nearly clear of ice the glacial waters escaped for a time westward into the Onondaga Valley.

Eastward is still another north and south valley involved in this history, that of Limestone Creek. The earlier local lake phenomena have not been studied, but the lower (northward) part of the valley was occupied by the hyper-Iroquois waters and related to the great eastward-leading river channels.

In the eastern valleys, Skaneateles, Otisco, and Onondaga, the later glacial lake history is intricate and with surprising changes of drainage. It will be noted that the later, local glacial waters drained westward—those of the Butternut Valley into the Onondaga, the Onondaga into the Otisco, the latter into the Skaneateles and this into the Owasco Valley, then occupied by the great Lake Warren. The westward-leading channels of these earlier waters are shown on page 251. When, however, Lake Warren found eastward escape, all these valleys were drained eastward with the lowering Warren or hyper-Iroquois waters.

Lake Newberry.

Origin.—The lowest of all the cols across the line of water-parting separating the present north and south drainage in New York is the one at Horseheads, the head of the Seneca Valley, with elevation of 900 feet. This great channel* is the final result of the erosion by the concentrated glacial drainage from the district lying between and including Honeoye Valley on the west and Owasco Valley on the east. Originally the channel carried only the overflow of the Watkins Lake and was doubtless somewhat higher than now, but the amount of the down-cutting has not been determined. The name "Watkins" lake applies to the waters as long as they were limited to the Seneca Valley. Lake Newberry may be regarded as having its birth when, by the recession of the ice front, the waters of either the Ithaca or the Hammondsport Lake were drained down to and became confluent with the Seneca Valley waters. Lake Newberry is therefore only the larger, more expanded Watkins Lake. The former name is used, not only as a matter of convenience but also for uniformity in glacial lake nomenclature; in order to distinguish the broad waters with complex relationship from the smaller, more localized, and simpler Watkins Lake.

Judging from the topography of the region, it seems more probable that the first local lake to lose itself in the Horseheads level was the Hammondsport. The locality of its overflow was probably near 2d Milo, four miles south of Penn Yan.

Extent and tributaries.—Upon the west, Keuka Valley became a gulf of the Newberry waters, first by the Penn Yan depression and later by the open valley to the north. Flint Creek Valley became a bay of the greater lake when the ice receded from the locality of Stanley and Gorham. The waters of Canandaigua and Honeoye Valleys were certainly tributary to the Hammondsport Lake through the Flint Valley, and probably continued tributary to the Flint Valley waters even after they were a part of Lake Newberry.

Upon the east, the Ithaca Lake found its close when the ice withdrew as far north as Ovid. The scourways made by the escaping Ithaca waters show an east and west erosion of the drumlin surface in and south of Ovid village. In the Cayug Valley the Newberry waters existed for a time sufficient t produce clear evidences of its presence, but as to Owasc Valley the evidence is negative. They may have existed ther a short time, or the ice dam toward the Canandaigua Valle may have lifted and drained Lake Newberry before the remova of that which barred the Owasco waters. The earlier Owasc waters (Moravia Lake) were certainly tributary to Lake Newberry by the North Lansing-Ludlowville channel and probabl were the easternmost of such tributary waters.

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* The Horseheads channel is described and figured in a former paper, Bull. Geol. Soc. Amer., vol. vi, p. 365.

Lake Newberry certainly included the valleys of Flint Creek Keuka, Seneca, and Cayuga Lakes, and possibly Owasco for brief time. In form the lake was an east and west belt o water resting against the ice front, and with four deep bay reaching southward up the valleys above named. Its linea extent was considerable, and its shoreline great, but its tota area was not large in proportion.

Shorelines and Elevations.—The phenomena of the Newberry shorelines have been observed, chiefly as terraces, an wave-built bars on terraces, of landstream deltas, throughou the Keuka and Seneca Valleys and in the southern part of th Cayuga Valley. These have all been described in detail i another writing[*] and it will be sufficient here to briefly mention the localities and altitudes.

In the Seneca Valley the Newberry shore phenomena hav been measured at many localities; at the head of the valle between Odessa and Montour Falls (Havana), 935 to 940 feet at Montour Falls, 950 feet (aneroid). On the west side, a Watkins, 960 feet; at Himrods, 990 (?) feet (aneroid); a Stanley 970 feet. Between Reed's Corners and Ennerdal occur the channels which drained the lake to the Warren level 985 feet to 930 feet (aneroid). On the east side of the valle are good delta ridges at Burdett, 964 feet; at Hector's Station 976 feet; at North Hector Station, 984 feet; at Lodi, 977 fee At Ovid the level is in the village, but the exact elevation i undetermined.

In the Cayuga Valley well-defined beach ridges occur a Trumansburg, 962 feet elevation. No effort has been made t locate the shore phenomena at other points, but they ca undoubtedly be found throughout the valley.

In Keuka Valley the main delta terraces throughout th valley are 955 to 970 feet elevation, and are attributed to Newberry waters.

The northward rise of these altitudes is evident and measurable, but the matter of beach deformation will not b discussed in this paper.

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[*] Glacial Waters in the Finger Lakes Region of New York, Bull. Geol. So Amer., vol. x, p. 27–68.

Am. Jour. Sci., Vol. VII, 1899.

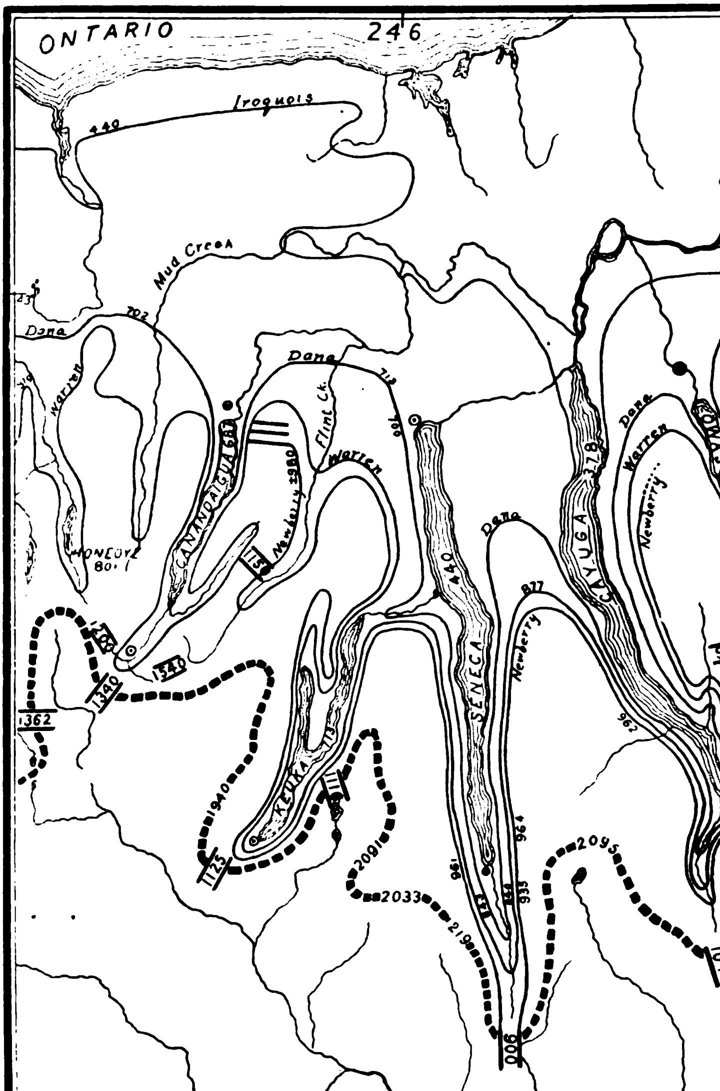
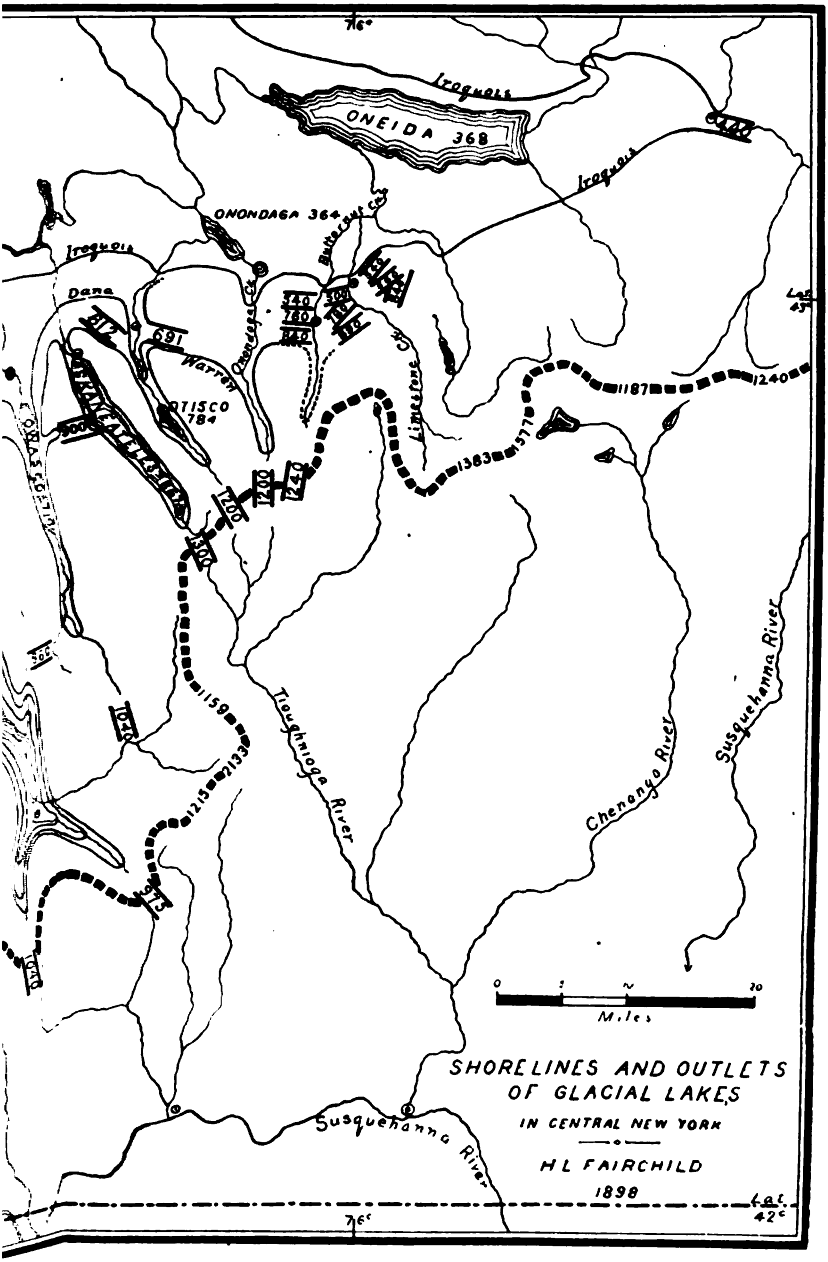


Plate VI.


76°
Iroquois
ONEIDA 368
440
Iroquois
ONONDAGA 364
Butternut Cr.
Iroquois
Dana
812
691
Warren
Onondaga Cr.
840
780
900
OTISCO 784
SKANEATELES
Limestone Cr.
Lat. 43°
1187
1240
577
1383
1240
1200
1120
1300
1159
2133
1215
360
1040
Tioughnioga River
Chenango River
Susquehanna River
0 5 10 20
Miles
SHORELINES AND OUTLETS OF GLACIAL LAKES
IN CENTRAL NEW YORK
H L FAIRCHILD
1898
Susquehanna River
Lat. 42°
76°

Extinction.—In the study of the glacial lake history, it was recognized that Lake Newberry must have been destroyed by outflow either to the east or west, eastward by the Mohawk Valley, or westward into Lake Warren. It was a matter of the quicker removal of the ice barrier in one or the other of two critical localities. And wherever the escape occurred we should find the scourways across the north-sloping land, or some transverse configuration with traces of erosion by the escaping waters, and with a favoring relation of valleys or openings beyond. With some knowledge of the topography of the critical east and west localities and their general conditions and relations, it was thought more probable that the Newberry waters escaped westward, and an examination of the eastern area at the foot of Skaneateles and Otisco Valleys, supplemented by a study of the Skaneateles sheet (unpublished) of the New York topographic map, confirms this view of the Newberry extinction. The writer has found no evidences of water at the Newberry level in the Skaneateles Valley, but such should occur if the waters found egress eastward, because the low Mandana pass (900 feet), east side of the middle of the valley, would have let in the waters long before the ice dam was removed from the high ground northeast of the valley. Indeed no conclusive evidence has been found of Newberry waters in the Owasco Valley, west of the Skaneateles. Moreover, the channel cut by the eastward escape of the subsequent and lower Warren waters lies only a few miles north of the high ground at the north end of Skaneateles Valley, and within this short distance of critical ground there are no east and west scourways or any evidence of water-flow between the Newberry and the Warren levels.

Lake Newberry was destroyed by draining westward over a point of land about five miles southeast of Canandaigua village, and midway between Ennerdale railroad station and Reed's Corners (see Plate VI). Here are well-defined and capacious channels, at successively lower levels, lying athwart the ice-moulded or drumlin surface. They occur on the south side of a morainal series and truncate the ends of drumlins. Here the Newberry waters were lowered to the Warren level, being drained from about 980 feet elevation down to 880 feet, and at the lower level the waters of the former Newberry area became a part of the great Lake Warren.

Lake Warren.

*General Description.**—This glacial lake was of great area. It is believed to have covered at least the southern part of the Huron basin, all of the Erie basin, and as much of the Ontario basin as was not still buried under the great ice-body. The beaches have been traced in the Huron-Erie basin and along the southern slope of the Erie and Ontario basins into Western New York as far east as the meridian of Rochester. The outlet of the lake was certainly westward into Mississippi drainage, probably across Michigan into the glacial lake Chicago. The name was given by J. W. Spencer.

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* A fuller description will be found in Bull. Geol. Soc. Amer., vol. viii, p. 269.

Invasion of Central New York.—The Warren waters existed in the extreme western part of the state, within the Erie basin, for a long time before they were allowed to enter the central part of the state. When the front of the ice barrier moved back, northward, from the high ground north of Batavia, Lake Warren extended eastward, as a relatively narrow belt of water, along the east and west ice-wall, with southward prolongations in the valleys. The waters occupied the valley of Oatka Creek to beyond Warsaw; of the Genesee and Canaseraga Valleys to beyond Dansville; the valley of Conesus, and ultimately the valleys of Honeoye, Mud Creek (Bristol), Canandaigua, Flint Creek, Seneca, Keuka (through Seneca), Cayuga, Owasco, Skaneateles, Otisco, Onondaga, and possibly Butternut. The valleys of Hemlock and Canadice were above the Warren level.

The breadth and southward extent of Warren waters in the valleys of Keuka, Seneca, and Cayuga were less than that of the Newberry waters, as they were about 100 feet lower. The northern boundary, the ice front, was probably much straighter or less lobate than that of Newberry. The glacial border being further north, on the low northern plain, the effect of the Finger Lakes valleys was nearly or entirely lost upon the ice-front, which was probably an arcuate line not far from the north ends of the present lakes.

Shorelines and Elevations.—The Warren shore has been traced with sufficient continuity to positively identify it as far east as Lima, south of Rochester, where it has an elevation of 879 feet. Well-defined beaches may doubtless be found further east, but the shoreline phenomena already discovered are delta terraces and bars and spits connected with deltas. Like the Newberry phenomena, these have been elsewhere described and need only be mentioned here.

In the Canandaigua Valley the Warren level appears upon the deltas, but the elevations have not been measured. A fragment of beach has been found southeast of Canandaigua village and one mile west of Reeds corners with elevation of about 880 feet. In the Keuka Valley the Warren level is very evident as the lowest of the strong delta terraces. These vary in elevation from 830 to 870 feet. In the Seneca Valley several terrace bars have been measured as follows: At Montour

Falls, 840 feet; between Montour Falls and Odessa, 840 feet; at Himrods, 853 feet (?); at Hector Station, 872 feet; at Lodi Station, 874 feet; at Ovid, 877 feet.

In the Cayuga Valley the Warren levels have been measured at Coy Glen, 831 feet, with a higher bench 865 feet; at Willow Creek, 829 to 863 feet; at Taughannock Falls, 826 to 849 feet; at Trumansburg, 829 to 834 feet. In the Owasco Valley, at Locke, 860 to 870 feet, and at Moravia, 855 to 882 feet (aneroid). The two levels in the Cayuga and Owasco Valleys are significant. These vary from 23 to 34 feet apart and are thought to represent the fall from the normal Warren level down to the first enduring level with eastward discharge, possibly the rock sill at the head of the channel southeast of Jamesville (see pages 251 and 260). The lower level is hypo-Warren, or, more accurately, hyper-Iroquois.

Extinction.—The life of Lake Warren was terminated by the opening of a new and lower outlet, eastward, past the ice-front, to the Mohawk-Hudson. For a long period, perhaps several thousand years, its waters had been tributary to the Mississippi, but for some centuries they had been creeping eastward along the ice front as if in patient search for a new escape that was sure to come. It should be kept in mind that the district we are considering has been uplifted to its present level since that time; it then lay at a much lower altitude.

The most western spillway of the eastern discharge of Warren waters is on the crest of the Corniferous escarpment four miles west-northwest of Marcellus village, and the same distance north-northeast of Skaneateles. The present elevation of the sill or intake at the lowest point is given by Mr. Gilbert as 812 feet, which is perhaps 80 or 90 feet under the theoretical Warren plane. There has been some removal of overlying drift and possibly of shale, and the intake has probably migrated backward to the present point. But this outlet, the "Gulf," was probably not the earliest nor highest spillway. In another writing (see reference, p. 256) reasons have been given for believing that the Warren waters at their full height invaded the region as far east as the Onondaga Valley and possibly the Butternut Valley. Their first and highest eastern escape was east of the Onondaga Valley, in the vicinity of Jamesville (see map, p. 251) and the waters were quietly lowered upon the hollows between drumlins at the head of the Gulf channel.

For years after the eastern escape was opened Lake Warren must have had two outlets and divided its contribution of surplus water between the Atlantic and the Gulf of Mexico; but soon after the Gulf outlet was opened it doubtless carried the entire overflow. Whenever this occurred the lake was no longer Lake Warren.

This large channel, excavated in Hamilton shales by the Warren overflow, leads southeast four miles, opening into the Otisco Valley two miles south of Marcellus village. The local name is the "Gulf," which, for want of a better name is retained. The waters were again impounded in the Otisco Valley, where the debris derived from the excavation of the Gulf was piled in a delta, with terraces from 860 down to 800 feet elevation. The Otisco waters (Marcellus Lake) escaped by another great rock channel, Cedarvale channel (named after a hamlet in the gorge) that heads at Marcellus village and leads southeast to the Onondaga Valley at South Onondaga.

These great channels, with others farther east (see page 251), show the final result of some centuries of erosion. Their initiation was probably not in the present geographic sequence, and the primitive conditions of elevation, etc., are uncertain. The Skaneateles and Tully sheets of the New York State topographic map will, when published, show the Gulf and Cedarvale channels and deltas with clearness.* Dr. Gilbert was the first to study these channels and to point out their relationship to those lying further east.†

Hyper-Iroquois Waters.

Lake Dana ("*Geneva*" *beach*).—At the time of Warren extinction the Ontario basin was still largely occupied by the glacier. Certainly most of the eastern part of the basin north of the locality now under discussion was filled with the ice. Considerable time was required for the front of this ice-body to recede so far as to permit an expanse of Ontario waters in the region under discussion, with immediate outlet at Rome—that is to say, for the westward expansion of Lake Iroquois. During this interval the glacial waters fell about 500 feet, from the Warren plane to the Iroquois. This subsidence was not a steady or continuous lowering, but *per saltum*,—a series of comparatively sudden falls, as progressively lower outlets were opened, with intervals of steady level, or very slow falling, as each outlet remained effective.

During one of these phases of repose it is believed that the beach was formed which has been traced along the west side of the Seneca Valley and described in a former paper as the "Geneva" beach.‡ It is also believed that the level of the beach correlates with the Cedarvale outlet at Marcellus. This is the only waterlevel between the Warren and Iroquois planes that has left any strong shoreline phenomena, so far as at present observed. Theoretically its evidences should be found from Marcellus westward throughout the Ontario and Erie basins, and it may be the subject of much future study. A distinctive name is required, and it is proposed to call the water Lake Dana, after Professor James D. Dana, the early leader in American glacial geology.

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* To the U. S. Geological Survey the writer is indebted for advance copies of the maps in manuscript which have facilitated this study.

† Old Tracks of Erian Drainage in Western New York, by G. K. Gilbert. Bull. Geol. Soc. Amer., vol. viii, p. 285.

‡ Bull. Geol. Soc. Amer., vol. viii, p. 281; vol. x, p. 44.

Since the publication of the former description the beach has been traced south from Geneva to near Dresden, and shoreline phenomena have been observed in the Cayuga Valley at a theoretically corresponding level. The elevations in the Seneca Valley are as follows: near Angus station, Fall Brook railroad, 671 feet; near Earle's station, 679 feet; west of Geneva, 700 feet; south of Phelps, 713 feet. The deformation of the beach is about three feet per mile, on north and south line, and it lies 180± feet under the Warren plane. Evidences of this lake should be found throughout the valleys of Cayuga and Seneca and westward at 170 to 190 feet under the Warren level. This water could not occupy the valleys of Keuka, Owasco, Skaneateles, nor Otisco, as these lie above its plane.

The magnificent Cedarvale channel, with its huge delta, has been described in another writing (see reference, p. 256). It heads on Corniferous limestone and shale, one-fourth mile southeast of Marcellus village, with an average elevation of 691 feet, which elevation correlates well with the beach altitude of the same parallel, something over 700 feet, making allowance for depth of water over the sill and the later down-cutting, with some east and west deformation of the land.

The change from the Warren level to the Dana level did not come by the slow down-cutting of the head of the Gulf channel, but by the recession of the ice front so that the glacial waters abandoned that outlet and found free access to the Marcellus valley from the north.

The eastern limit of Lake Dana was practically the same as that of Lake Warren, but with a surface 180± feet lower. Its southern margin must have been more contracted, while the ice boundary upon the north was somewhat further removed. Its western limits have not been determined, but phenomena attributed to this water have been observed as far west as the Genesee River. Without some unexpected barrier, like great land elevation or far readvance of the ice sheet, there seems no escape from the conclusion that Lake Dana must have covered the Erie basin. Being weak as compared with the Warren phenomena, these have been overlooked, but it is predicted that they will be found westward over a wide area. The hypothetical shoreline is indicated on the map.

Water levels between Lakes Dana and Iroquois.—In the district south and east of Syracuse there are several other abandoned channels. All are lower than those described above; some of them are in rock and of great capacity. The most interesting ones are the sluiceways which carried eastward the overflow of Warren and Dana Lakes, and which constitute, with the Gulf and Cedarvale channels, a connected series (see page 251). All this series lie transverse to the present drainage and conveyed eastward, across the intervening high lands, the waters impounded by the ice-dam in the north and south valleys. The flood poured into the Onondaga Valley from the hypo-Warren and Dana Lakes by the Cedarvale channel was carried over to the Butternut Valley by three successive channels lying southeast of Syracuse and near Jamesville. The lowest and most important is a great "rock cut," three miles southeast of Syracuse. While perhaps not the largest, this channel is the finest, the most typical, and the most easily seen of any glacial channel in New York. It is about three miles long and is traversed, its whole length, by the Delaware, Lackawanna & Western railroad, and has been named the "Railroad" channel. The walls are nearly vertical bare rock, 125 to 150 feet high, and the bottom of the cut will average 900 feet wide.

The water was conveyed eastward from the Butternut Valley to the Limestone Valley by other great rock channels, the largest and latest one heading opposite the mouth of the Railroad channel and extending somewhat over three miles to High Bridge, south of Fayetteville. The Syracuse sheet of the topographic map well portrays the Railroad channel, but the High Bridge channel is not well delineated on the north side by the 20-feet contours. From the valley of Limestone Creek three channels lead northeast; the highest of these heads in a cataract, one and one-half miles southwest of Mycenae, and joins the second channel, which ends at Mycenae above the Iroquois level. The lower waterway holds Round and Green Lakes, which occupy depressions produced, as pointed out by Dr. Gilbert, by the sinking of strata due to solution of the underlying salt beds. The heads of these three channels are higher than the High Bridge channel, and they probably ceased to be effective earlier. Indeed they were probably the first of the east and west series to be abandoned, excepting the 890 feet ("Green's") channel, south of High Bridge.

Northward of the outlet series described above, lies another, later, series of channels. The Syracuse sheet exhibits a broad channel, heading a mile east of Fairmount at 500 feet elevation, which passes eastward directly through the center of Syracuse, where its elevation is only 400 feet. West of Syracuse they have not been mapped, but another and lower watercourse may be seen from the Auburn branch of the New York Central railroad, heading in a cataract west of Marcellus station and followed by the railroad eastward to beyond Camillus.

It is possible that one or more of the channels lower in elevation than the Cedarvale channel may have established for a short time an independent lake level, but such waters could not have extended westward beyond the Ontario basin, as the planes of these outlets are below that of Niagara.

Upon the north sides of these channels the morainal drift is heavy and the topography more irregular than shown by the topographic sheets.

Lake Iroquois.

These latest glacial waters of the Ontario basin have been so long known that extended description is unnecessary here. The name was given by J. W. Spencer, and Mr. Gilbert correlated the shorelines with the col and ancient outlet at Rome. This large and important body of water had a long life, during which it matured its western shorelines and expanded to an area larger than that of the present Ontario, as its surface was far higher than Ontario, although the retreating ice barrier during most of the life of Iroquois held possession of some of the northern or northeastern part of the basin.

During the life of Iroquois the differential elevation toward the north-northwest, or canting of the basin toward the south-southwest, produced a shifting of the shorelines, a transgression of the waters upon the southern shores and a recession from the northern shores. This has been graphically shown by Dr. Gilbert.*

The Iroquois shoreline was not matured east of Sodus although abundant evidence of the water-action exists. South and east of Sodus Bay the map gives only the general or hypothetical position of the water line.

The lake became extinct by the opening of the St. Lawrence Valley and lowering of the water below the Rome outlet. At this time the altitude of the basin was such that the head of the St. Lawrence channel, at the Thousand Islands, was below sea-level, and a gulf of the ocean occupied the Ontario basin. The differential uplift, however, soon barred the sea and initiated the present lake and river.

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* "The History of the Niagara River," 6th Ann. Rept. Com. of State Res. of Niagara, Albany, 1890.

ART. XXVI.—*A Rapid Method for the Determination of th Amount of Soluble Mineral Matter in a Soil;* by THOS. H MEANS.

A RAPID and simple method for the determination of th per cent of soluble matter which a soil contains has been foun very desirable where areas of soil are to be studied in an detail. Particularly is this true in the arid and semi-ari regions of the West where accumulations of soluble salts hav been the cause of injury to valuable tracts of land. The ordi nary methods of chemical analysis are entirely too laboriou for the examination of a large number of samples, and, beside chemical analyses cannot be made out in the field. In fiel studies it is of great advantage to know the salt-content of th soil at hand. The accumulation of "alkali," wherever irrigatio has been practiced a few years, has pointed out the great neces sity of studying the conditions of the soluble matter befor water is applied. Enormous sums of money are being investe in irrigation, and a great deal of this expended capital ha been, or will be, lost unless new systems of irrigation an drainage are devised. There can be no question that the stud of the soil, the alkali and the methods for the prevention o its accumulation, must form an integral part of every irrigatio engineering problem. Not only must the surface of the so be examined, but the per cent of salt found in the subsoil to depth of 30 or 40 feet should be known. In order that unde ground maps of the salt may be prepared with much greate ease than is possible with ordinary means, the followin method is suggested.

The electrical conductivity of water varies with the amoun of dissociated salt that is present. The method is practically means of determining the specific electrical conductivity (o resistance) of the solution between the soil grains. When thi is known, the amount of any salt which will produce this sam conductivity may be calculated from published tables of th conductivity of salt solutions.*

In order to determine the effect of the solid grains of th soil upon the resistance of the solution, the following exper ment was arranged. A hard rubber cell with parallel sides o metal was partly filled with a solution of known specifi resistance. Then as much dry soil was added as would b taken up by the solution, forming a saturated soil. Th resistance was in all cases increased. A correction was mad for the soluble matter contained in the soil, and the increase i resistance, due to the addition of the solid non-conducting particles, was therefore determined. In this way a large number of samples were examined and it was found that the increase in resistance was nearly the same for soils of very different textures. The following table contains the most important of the results:

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* Kohlrausch, Wied. Ann., 1879, vol. vi, p. 145.

Number of determinations.	Soil and character.	Per cent water when saturated.*	Initial resistance. Ohms.	Resistance after soil is added. Ohms.	Factor of texture.
10	Loess, Virginia City, Ill. Silty	31·84	1	1·81	·551
10	" " " "	35·36	1	1·73	·579
10	Limestone soil, Blacksburg, Va. Heavy clay	69·41	1	1·90	·527
10	" " " " "	72·49	1	1·85	·542
5	Red Land, S. C. Clay soil	40 00	1	1·83	·557
5	" " "	36·35	1	1·88	·533
5	" " "	32·75	1	1·93	·517
10	Sea Island. Cotton soil, S. C. Fine sand	25·77	1	1·83	·547
10	Early Truck soil, Md. Coarse sand	17·94	1	1·78	·563
				Average	·548

These soils, as seen in the table, vary from the light sandy lands, which require less than 18 per cent (of their dry weight) of water to saturate them, to the heaviest of clays, requiring 70 per cent of water for saturation. Determinations were made with two or three amounts of water in some of the soils in order to strike as near as possible the point of saturation. The last column is the ratio between the resistance after the soil was saturated and the initial resistance of the solution. If the resistance (between parallel electrodes) of a saturated soil is multiplied by this figure (the factor of texture), the resistance of the solution between the soil grains will be found.

The salt determination is performed in practice as follows:

1. Saturate the soil with distilled water. The point of saturation can very easily be found and, with a little practice, duplicate samples can be mixed to within a small error.
2. Pack saturated soil in a cubic cell with two sides of metal and take the resistance. Read the temperature, and correct resistance for temperature.† Multiply the corrected resistance by the factor of texture, 0·55. This gives the resistance of the soil solution alone in the cubic cell.
3. From the known weight of soil in the cell and the percentage of water required to saturate the soil, find the number of cubic centimeters of soil moisture between the soil grains. In field work it is sufficiently accurate to take the average of

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* Calculated on dry weight of soil.

† Bulletin 7, Division of Soils, Department of Agriculture. Bulletin 8, Division of Soils, Department of Agriculture, page 27.

several laboratory determinations of this quantity. The amou of soil moisture being known, the cell factor (the figure b which the resistance must be multiplied to obtain specifi resistance) for this quantity can be found.[*]

4. Multiply the resistance found in (2) by the cell factor an obtain the specific resistance of the soil solution. For dilu solutions the per cent of salt present is nearly inversely pr portional to the resistance. In a study of the alkali soils the West[†] where the salts are of rather uniform chemical co position, it is of great advantage to have a more accura method of calculating the results. In such studies, a solutio of the average composition of the salts is made up and it resistance-salt curve determined. In this way the per cent salt by weight can be reckoned for any resistance. Such a pr ceeding was followed in some studies of alkali soils in Montana.

This method offers special advantage in the study of alka soils. The apparatus necessary can readily be carried in th field. A convenient form of Wheatstone's bridge adapted t field use has been designed by Mr. Lyman J. Briggs of th laboratory.

The auger for sampling the soil is in general use in the stud of surface geology.[§] The only other apparatus necessary ar the cubic cell,[‖] thermometer, mixing dish and bottle of di tilled water.

This method offers a ready means for the detailed study o irrigated districts. Two men can examine from sixty to on hundred samples of soil in a day and in this way cover co siderable ground, obtaining sufficient data for the constructio of salt maps of the district.

U. S. Department of Agriculture, Division of Soils.

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[*] Ostwald's Physico-Chemical Measurements, translated by Walker. page 22 Note.—If a cubical cell is used—such a cell 4^{cm} internal dimensions has given m the best results—the cell factor will vary inversely as the number of cubic cent meters of solution present.

[†] Whitney and Means, Bulletin 14, Division of Soils, Department of Agricultur

[‡] Loc. cit.

[§] Darton, Am. Geol, vol. vii, page 117–119.

[‖] Whitney and Means, Bulletin 8, Division of Soils, Department of Agricultur page 11.

ART. XXVII.—*On a New Type of Telescope Objective especially adapted for Spectroscopic Use*; by CHARLES S. HASTINGS.

THE ordinary achromatic doublet as invented by Dolland in the last century, is, as is well known, very far from complying with the condition implied in its name. For telescopes of small aperture, or even for those of very considerable aperture, if a ratio of focal length to aperture as great as that customary with Dolland be employed, the defect in color correction is neither very conspicuous nor very harmful in ordinary use. But if the apertures are very large, as in our modern astronomical instruments, or if the length be reduced relatively to the diameter of the objective, this defect of secondary color aberration becomes very conspicuous and reduces the optical efficiency of the instrument very materially. The maximum inconvenience of the defect, however, falls upon the spectroscopist, who finds that, although the optical efficiency of his instrument is independent of the wave-length of light which he happens to be observing, the instrumental adjustments must undergo frequent changes for adaptation to different portions of the spectrum. Another familiar and obvious consequence of the secondary color defect is the impracticability of adapting the same instrument to purposes of both eye and photographic observation.

It follows, therefore, that the solution of the problem, apparently first seriously undertaken by Fraunhofer, namely, to devise an absolutely color-free objective, is, and has long been, of continuously increasing moment. Fraunhofer failed; but unless I greatly misapprehend the meaning of his own record of his work, the effort led directly to the discovery of the Fraunhofer lines and to the beginning of spectroscopy. It is true that nowhere, as far as appears in his published writings, does he state that this was his aim; but in view of his very extended experiments in varying the constitution of his glasses, of his studies of the minute dispersion characteristics of various substances, and of the extraordinary skill and conscientiousness in perfecting an instrument which has possessed no other error of importance since his unequaled contributions to the art of telescope-making, few will question the validity of the inference.

Doubtless many investigators since Fraunhofer's time have attacked the same problem, but, so far as I am aware, without any recorded success until the writer showed, in a paper published in this Journal, vol. xviii, p. 429, that there were certain glasses, unfortunately not then procurable, which would yield in a triple combination an objective entirely free from color. Since then the extraordinary increase in number of materials at the command of the optician, resulting from the labors of Dr. Schott of Jena, led the writer to return to the problem with the results which were published in a paper in vol. xxxvii of the same Journal, in 1889. A general method of dealing with all such problems was there developed and a number of triads were indicated which would yield the most favorable results. It is true that those given included a phosphate glass which was believed by the makers to be permanent and has since proved not to be so; but it was distinctly stated that the table exhibited a considerable number of other promising combinations, and the general method of recognizing them was pointed out.

It may properly be stated here that the latter paper also contained a general discussion of interesting double combinations, one of which promised to be of great value to spectroscopists; but the inability of glass makers to supply large disks of the materials in question proved an unforeseen difficulty. Still, the writer employed this construction for a number of years for his spectrometer and only displaced it recently by an improved type of objective. Professor Keeler has also employed the same construction, made by Mr. Brashear with my aid, satisfactorily in spectroscope work.

The experiments with triple combinations which followed the paper last named met with an unforeseen difficulty. The particular triad which promised most in theory proved to have in one of its members a perishable glass. This might possibly have been used by covering the objectionable material by a more permanent glass cemented to it, but this course is not without risk, and certain defects, to be noted later, are not so readily eliminated if this method be chosen. The only practicable course seemed to lie in replacing this material by one beyond suspicion, and much time was spent in investigating the possibilities of this meams. It was found, as appears from the paper cited above, that there was no difficulty in selecting triads which would meet the analytical condition, insuring complete elimination of color and subject to practical limitations as regards permanency; but the necessarily greater curvatures of the lens surfaces introduced a new source of imperfection, namely, chromatic difference of spherical aberration. Of course, this, like all other errors, is present to a greater or less degree in all optical instruments which depend in any way upon refraction for their action. In telescopes, however, this error has never been sufficiently great to betray itself to the users, although clearly indicated by theory. Gauss, indeed, a long time ago showed how to reduce this particular error to a residual of a higher order of minuteness, but the fact that his construction has never come into use is a most convincing proof that the error is quite negligible as compared to other defects inherent in the ordinary construction. But when we try to make a color-free triple objective after the methods of the paper of 1889, we find that the defect in question becomes of great moment. Especially is this true if we prescribe the cementing of the objective so that there shall be only two free surfaces. Such an objective, if corrected as regards spherical aberration for light-waves of mean length, would have strong positive spherical aberration for the red and negative for the violet ends of the spectrum. It is true that this defect might not prove very obvious for a telescope which is to be used only for objects which are approximately white, but it would be intolerable in spectroscopic use. The obvious method of reducing the error is to increase the ratio of the focal length to the aperture. This method, however, would introduce such serious structural and mechanical difficulties, and so far reduce the convenience of handling all spectroscopes to which it might be applied, that it seemed to me quite impracticable.

As a possible means of securing the end in view, convinced as I am that its importance warrants any amount of labor, I lately turned to a consideration of the possibilities possessed by a combination of four varieties of glass. The investigation is necessarily somewhat laborious as appears from the unusual conditions imposed from the outset; but the time expended in attaining complete success was short compared to the protracted investigations which led to a definitive rejection of the triplet as quite inadequate. In short, I have constructed an objective, consisting of a quadruple combination of silicate flint, borosilicate flint, silicate crown and barium crown, which possesses all the properties demanded. It has but two free surfaces, the four lenses being cemented together. With an aperture of one-tenth the focal length, its focal plane is rigidly the same for all wave-lengths, from that of the Fraunhofer line A to that of K, while it is sensibly free from chromatic differences of magnification and of spherical aberration. With its perfect color correction, the well-known (but ordinarily overlooked) chromatic aberration of the eye becomes very sensible. This, however, I have eliminated by means of a specially devised ocular, so that in my instrument there is no reason why its length may not be made permanently invariable. One notable advantage in the construction will appear at once to all spectroscopists: wave-surfaces from the collimator being rigidly plane for all wave-lengths, the adjustment of the prisms for minimum deviation—provided always that their faces are accurately plane—ceases to be of importance. Thus a construction, which must have occurred to every one who has seriously studied the theory of the spectroscope, in which the last prism of a train is of half the angle of the remainder and silvered on the back, so that the light retraces its course through the train, becomes entirely practical. Indeed, my experiments with the new telescope lead me to prefer a construction of spectroscope in which the collimator and telescope are set at constant angle, and the prisms, arranged as above, are alone movable. This is the familiar construction of the grating spectroscope.

Although the objective described above consists of four lenses, I imagine that a cemented system of five lenses would in some cases be preferable, especially in relatively large apertures; but there is no doubt in my mind that four kinds of glass are sufficient and, unless greater structural complexity is admitted, necessary for the ends defined.

Should the construction meet my confident expectation and supply the spectroscopist with an optical instrument combining the merits of a reflector with the greater merits of a refractor, it will be convenient to give it a characteristic name suggested by its properties. These are, as given above, chromatic differences of focal distance, of focal length, and of spherical aberration, all reduced to practically zero, together with a minimum possible number of free surfaces. As such an objective is the same in its action upon light of all wave-lengths, I propose to call it an *isokumatic* system.

Mr. Brashear of Allegheny, who made for me the prisms for the study of these glasses, as well as scores of others, and who has shown unfailing good nature and constant readiness to lend me his efficient aid in all my optical investigations, merits my unstinted acknowledgments. I have promised the necessary calculations if he is called upon to carry out for others this difficult piece of optical work which has yielded so much satisfaction to the writer.

Yale University, March, 1899.

ART. XXVIII.—*On the Phenocrysts of Intrusive Igneous Rocks;*[*] by L. V. PIRSSON.

THE igneous rocks, excluding those which have solidified as uncrystallized glasses, may be roughly divided into two classes, the *granular*, composed of mineral particles of approximately similar size, and the *porphyritic*, consisting of minerals exhibiting a more or less perfect outward crystal form which lie embedded in a so-called groundmass made up of much smaller, usually anhedral,[†] particles or even wholly or in part of glass. A rock belonging to this latter class is a *porphyry* and the larger embedded crystals are called "porphyritic crystals" or more conveniently "*phenocrysts*," a term proposed by Iddings which has obtained general recognition among geologists.

It is with respect to the origin of these phenocrysts in a certain class of igneous rocks that it is proposed to treat in this article.

Without going into details, it will be sufficient to recall that many petrographers have expressed the view that the phenocrysts of porphyritic rocks, by the very fact of their size, frequent perfection of crystal form and contrast of character to that of the groundmass in which they lie embedded, are older than this groundmass, have been formed under different physical and therefore different geological conditions, in short, not in the place where they now are, but at great depths, and hence they are frequently spoken of as "intratelluric" in origin.[‡]

The writer has been unable to find in the literature, that any sharp distinction has been drawn between the origin and character of the phenocrysts of *intrusive* igneous rocks and those of the *extrusive* ones or lava flows. This has probably arisen from the belief that phenocrysts are always formed, as stated above, at much greater depths than the place in which they are now found, and that therefore their origin is similar in both cases. It would thus make no difference in regard to their origin and character, whether the ascending magma which contained them was thrust in intrusive masses into the upper portion of the earth's crust or poured out on the surface in flows of lava.

In the present article, however, it is to be carefully noted that the writer confines himself to the phenocrysts of the *intrusive* rocks, as it is intended to show that not all phenocrysts are intratelluric in the sense that they have been formed at much greater depths than they now occur in, but that on the contrary in many cases they have been formed in place, and are of contemporaneous origin with the other constituents of the rocks, and the nature of the proofs is partly such that they can be applied only to intrusive rocks, and partly they have not been observed in lavas.

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[*] Read before the Geological Society of America, December, 1898.

[†] i. e., having crystal structure but not crystal form.

[‡] Rosenbusch, Mass. Gest., 3d ed., 1896, p. 553; Michel-Lévy, Struct. et Class. des Roches, 1889, p. 1 et seq. See also discussion by Zirkel, who does not follow this view, Lehrb. der Petrogr., 2d ed., 1893, vol. i, p. 737 et seq.

The idea that phenocrysts are not necessarily intratelluric has been expressed by previous writers, and Zirkel* indeed gives a very full discussion of the subject, while Cross† also mentions this belief in alluding to orthoclase phenocrysts which are found in certain laccoliths but not in the peripheral portions. But the subject does not appear to have received in general the attention that its importance merits, and the writer is therefore led to present his own observations bearing on this point, and the deductions he has drawn from them as a contribution to the subject. They have been gathered during the progress of the geological work in Montana, by Mr. W. H. Weed and the writer, and the details have mainly appeared in our publications on that region, but they are now gathered together and generalized for use upon this question. Similar proofs of course occur elsewhere, and they are indeed of general application.

Meaning of intratelluric.—The term "intratelluric" needs a moment's attention. It is probable that different writers have used it with somewhat different ideas, differing as to degree, not as to kind. Nowhere has the writer been able to find a precise definition by an author of what his idea of intratelluric is, but it is certain from the context, that in all cases, as regards *time* and *niveau*, it means an earlier period and greater depth of the magma than that in which it came to rest. Thus in a laccolith formed under a great thickness of sediments, the phenocrysts would be spoken of as the constituents formed in the intratelluric period, that is a lower, earlier period of the magma and in contrast to the groundmass, which is never spoken of in these cases as intratelluric.

Whatever exact ideas writers may have had regarding this term, it may be taken as well assumed that it means a deeper and therefore earlier stage of the magma in the earth's crust, than any in which the intrusive porphyritic rocks have been formed.

Two classes of phenocrysts.—Phenocrysts may be divided into two general classes. First, those which are found only as distinct porphyritic crystals and do not occur as a mineral component of the groundmass, like the micas and hornblendes of many acid rocks, and the olivines of many basic ones; and second, those minerals which are formed both as phenocrysts and also in the groundmass, like the quartz and feldspar of acid rocks and the pyroxenes of basic ones. The second class may be termed *recurrent* phenocrysts, meaning that the mineral composing them occurs both as a phenocryst and in the groundmass; Rosenbusch suggests the term in speaking of the recurrence of mineral formation. The other, or first class will be called here monogenetic phenocrysts. This distinction is of importance, as it is chiefly with the recurrent phenocrysts that we shall have to deal.

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* Lehrbuch der Petrographie, vol. i, p. 737 et seq , 1893.

† Laccolitic Mountain Groups, U. S. Geol. Surv., 14th Ann. Rep., 1895, p. 231.

The proofs that all phenocrysts of intrusive igneous rocks are not intratelluric, but have in many cases been formed in place, and contemporaneously with other constituents may be divided into two classes, those which are megascopic, that is to say, geological or may be observed in the field, and those which are microscopic, or to be gathered by a study of thin sections. The geological proofs will be considered first.

Evidence of contact zones.—In the case of many laccoliths, dikes, sheets and other intrusive masses of igneous rocks of the more acid feldspathic kinds, it has been observed that while the main rock masses are highly porphyritic, often containing phenocrysts of great size, they pass into peripheral zones, which may attain considerable width, in which such phenocrysts are entirely wanting. The border zone is often observed to be dense, aphanitic and totally without phenocrysts either great or small—the constituents are all of one period of formation and allotriomorphic in structure.*

But if the magma contained phenocrysts before coming to rest, they should occur in the border zone as well as elsewhere. It will not do to suggest two separate intrusions in these cases, for the geological "*mise en place*," and the whole character of the occurrences, utterly forbids such a supposition. Nor will it do to say that they previously existed in the border zone, but were redissolved. For the border zone being the part cooled first and most quickly, if they previously existed in it, then there is especially the place where they should occur. If any re-solution should take place, it would be in the center, not at the sides. Nor will it do to partially compromise the matter by saying that in the original magma they were very small and grew greatly after the magma came to rest.

No doubt this often does happen, but in many cases, as stated above, there are *none* in the contact zone, nothing to represent the thickly swarming masses of them in the central portion. In these cases the writer sees no escape from the conclusion, that the phenocrysts were formed in place. The evidence is most common and striking in regard to phenocrysts of the recurrent type, but it has been also observed in those of the monogenetic type.

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* Zirkel mentions similar instances, loc. cit., p. 740.

Evidence of dikes and sheets.—In many cases we have clear and indisputable evidence, that systems of dikes and sheets have been formed by a single geological act; that is, filled from a single parent magma, at the same time and under the same conditions, and they have of course the same chemical composition. An example occurring in the Judith Mts.* of Montana has been recently described by the writer. The attendant fringing sheets lying above many laccoliths may also be cited as examples. Yet in many of these cases some sheets or dikes may have large and well-developed phenocrysts, others none at all. The laccolith may be full of phenocrysts; its attendant sheets or some of them may be entirely devoid of them. A sheet of tinguaite in the Judith Mts. contains phenocrysts of feldspar as large as one's hand, but a narrow sheet of the same rock which the general geologic history of the district shows was intruded at the same time, and which has a similar composition, has only very minute ones arranged in flow structure. In these cases, had they previously existed in the parent magma, they should be found in both alike. The conclusion in these cases is that the phenocrysts have formed in the places where they now are.

Evidence of fluidal phenomena.—In the case of some dikes and sheets it has been noticed that the phenocrysts of feldspar, which have a flat tabular form, have a definite arrangement throughout the mass, with the flat sides parallel to the bounding walls, or in other words, as it is commonly called, a "fluidal" or "flow structure." Sometimes they are rather irregularly distributed, collected in groups or in lines, and are just as apt to occur close to the border zone, at the bounding wall, as elsewhere in the dike. Such instances show clearly the effects of tabular plates being moved along in a liquid, and they prove that the phenocrysts were formed in the magma before it came to rest. How long before we are of course unable to determine, but in these cases they may be "intratelluric," so far as any definite meaning can be attached to this term.

In other dikes and sheets, the phenocrysts have no oriented arrangement in the mass, their orientation is wholly haphazard, they occur evenly distributed throughout, or they may be very small or of different character, or even wholly wanting in the border zones, and this in spite of the fact that they may have a pronounced tabular development.

If in the former cases mentioned the evidence proves that the phenocrysts were formed prior to injection, then the absence of such evidence, that is to say its converse, proves just as clearly that these flat phenocrysts were formed after injection when the magma had come to rest or in other words in place.

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* 18th Ann. Rep. U. S. Geol. Surv., pp. 551 and 572, 1898.

Moreover these flat phenocrysts, whether oriented or not, are
great value in throwing light on another question in theo-
ic petrology—whether phenocrysts ever move in the magma
er it has come to rest; that is, whether they sink down in
edience to gravity. In the cases mentioned it is clear that
ey have not moved or they would have arranged themselves
obedience to the laws governing the movement downward
flat plates through fluids; they would be disposed with their
t sides downward or perpendicular to the walls of the dike.
e writer has never seen such an occurrence nor been able to
d any description of one, and until such a case has been
ınd the evidence is against the idea that phenocrysts sink
rough gravity and evidently because the magma is too viscous.
ey could not assume such a position in an upward moving
gma because the motion must be differential and would arrange
em in the opposite direction; hence this orientation would
ow that they had moved and not the magma. The thicker
cumulation of phenocrysts at the bottom of an intruded
eet, which has sometimes been noticed, would not prove they
d fallen through gravity unless they had this arrangement,
ce that may merely show that the physical conditions neces-
y for the production of phenocrysts were more favorable
d operative there than in the upper portion.

To return again to the formation of phenocrysts in place,—
m the evidences given above, when we find that in dikes
d sheets flat tabular phenocrysts such as the feldspars of
ny acid rocks or the large mica tables of certain basic ones
scattered without orientation, we may conclude that they
ve been formed in place and are not "intratelluric."

Evidence of porphyritic granites.—It is well known that
ny granites contain large porphyritic feldspars, often of
at size. The granites may have so coarse a grain that in
absence of these feldspars no one would think of them
other than typical granular rocks. The same is also true at
es of other rocks besides granites. The evidence that
se afford is chiefly of a negative kind, but it is useful to
sider in this connection. It is evidence not so much of the
e and *place* of the formation of phenocrysts as of the *cause*
d *manner* of formation. To treat these questions fully
uld lead us into the discussion of the "*mise en place*" and
structure and classification of igneous rocks, which would
beyond the limits of this article. It will therefore be suffi-
nt to ask one or two questions. Are these large phenocrysts
granites to be considered intratelluric or not, or is granite
lf and all its constituents to be regarded as intratelluric?
e difference between the porphyritic and the granular struc-
es has been regarded by some, so far as their origin is con-

cerned, as a difference not alone of *degree* but of *kind.* If so, what is this precise difference and why should granular rocks ever possess a porphyritic structure?

What the significance of these crystals really is according to the author's belief will be shown later on.

Microscopical evidence.—We now come to those proofs which are to be seen in the minute internal structures of the phenocrysts when seen in thin section under the microscope. They may be divided into two classes, *external*, or to be seen in the minerals surrounding the phenocryst, and *internal*, to be seen in the minerals which the phenocryst encloses. We will consider the latter first.

Internal evidence.—While the majority of phenocrysts are homogeneous and free from inclusions, in a large number of cases they are not, but contain the other rock minerals. These are usually those of an older period of formation, such as apatites and ores, and their explanation appears simple, but in some instances the phenocrysts may enclose *all* the other rock minerals including crystals of the same mineral as they themselves are composed of. Thus large orthoclases are seen enclosing other orthoclases and quartz. If the enclosed mineral has the same composition and a similar orientation as the phenocryst, it becomes of course an integral portion of the crystal and the enclosure cannot be detected, but it often does not and is then readily identified. In these cases it is impossible to avoid the conclusion that not only was the phenocryst formed in place but contemporaneously with the other minerals. At such times the included minerals are scattered throughout the whole extent of the phenocrysts, but often they are found only in outer zones, indicating that the inner portion had formed first and that later the phenocryst was growing and expanding while the groundmass was crystallizing and was thus including it.* The ability of crystallizing material to orient itself over considerable areas and enclose the other constituents is well illustrated in the poikilitic structure as seen in the quartzes of rhyolites, the orthoclases of shonkinites and the hornblendes and micas of the very basic rocks.

External evidence.—But growing and expanding phenocrysts do not always enclose the other minerals of the groundmass with which they come in contact. On the contrary, like all crystallizing substances, they endeavor to exclude impurities and more commonly they reject and push them along as they grow. Usually the minerals which make up the groundmasses of porphyritic rocks have an isodiametric development, they have therefore no orientation as regards form, and it is hence difficult to tell whether such particles lying alongside phenoysts have been rejected and pushed or not. In certain cases e microlites of the groundmass have however an unequal velopment—they may be thin flat plates like the feldspars of me trachytes and andesites or slender rods like the ægirites some phonolitic rocks. In such cases it is common to serve that the microlites have a length orientation parallel to *ch* face of the large crystal forming the phenocryst, and not ly this but the larger the phenocryst is, the more evident is becomes; they have been more crowded and the arrange- nt is more evident. This applies of course only to those crolites in the immediate neighborhood of the phenocryst. the case of the large feldspar phenocrysts of some Montana gnaites the crystals are covered with a perfect felt of simi- ly oriented ægirite needles.* The arrangement is precisely at would happen if a scattered group of matches lying on a ble should be swept to one side by a book and was caused thout doubt by a quite similar process.

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* These Montana instances give additional force to those mentioned by Zirkel in his discussion of the subject, loc. cit., p. 747.

Such arrangements have been largely either overlooked or obably confounded with fluidal or flow structures. The lat- r, caused by movements or currents in the crystallizing gma, is however easily told, since in that case all of the con- tuents of the period are alike affected, both phenocrysts and crolites being drawn out into waving lines or streams, while case the orientation is produced by the expansion of the enocrysts the microlites are arranged parallel to each of its ystallographic faces, have no orientation in the interspaces d the phenocrysts themselves have also no orientation. This *pansion structure*—to coin a term for it—around phenocrysts ay of course occur in combination with fluidal structure and erge into it, but typical cases of it are easily told and should more generally noted in petrographic descriptions.

This evidence then goes to help the general proposition that ne phenocrysts are formed in the places where they now are, they were expanding and growing vigorously while the oundmass was crystallizing and a magma whose groundmass crystallizing has already reached the place it is destined to cupy.

Summation of evidence.—The value of evidence is cumula- e and increases, not in an arithmetical, but in a geometrical io. A single fact may indicate definitely a certain hypothesis its explanation, but it may also be an exception to a general le. When we can bring a second fact to support it, the obability of the correctness of the hypothesis is greatly reased, and when a considerable number of such facts are und, all pointing to the same explanation, we may reasonably nsider it as proved. Thus, when we find that a dike con- ns flat tabular phenocrysts, which show no orientation, and are nting in the border zone of contact and contain all the other rock constituents, and when this dike is one of a set filled by the same injection which may or may not have similar phenocrysts, we are thoroughly justified in assuming that its phenocrysts are formed in place and are not intratelluric.

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* This Journal, IV, ii, 1896, p. 191.

Evidences of intratelluric origin.—We should now consider the evidences on which is based the view that phenocrysts have been formed at great depths under wholly different conditions from the other rock constituents. So far as the writer can discover, they are these,—the contrast in size and crystal form of phenocryst to the constituents of the groundmass, the fluidal arrangement the phenocrysts sometimes possess and the fact that they are often corroded or changed in character, that is resolved.

But the contrast of form and size, as we shall presently show, may be explained in quite a different way; the fluidal arrangement certainly shows that the phenocrysts were formed before the magma came to rest, but it does not show how long before or that it may not have been just previously; while the corroded and altered crystals show a change of *conditions*, not necessarily a change of *place*, and although this may be a logical inference it is still not the only one.

From the facts at our command, therefore, it appears most reasonable to say that in some cases we know that phenocrysts have been formed in place; in other cases we know that they were formed prior to injection, but how long and how far we do not know, and that in the great majority of cases we do not know whether they were formed in place or not. It is the author's belief that the majority are formed in place for reasons which it is now proper to give.

Conditions governing the formation of rock structure.—So far as the writer can understand, the French believe in two distinct and different periods of consolidation for all intrusive rocks both granular and porphyritic; many if not most of the Germans believe in one for the granular and two for the porphyritic; like some petrographers, the writer sees no *necessity* for more than one in both.

The conditions governing the consolidation and crystallization of an igneous magma are complex, and many of them, perhaps all, are as yet ill understood. The fall of temperature is the most important, but the chemical composition of the magma, the influence of mineralizing vapors and the pressure are also of great importance. Another important consideration which has been greatly overlooked is increasing viscosity, which depends on chemical composition and temperature. It would be impossible to discuss all these in full, and the writer therefore confines himself to a brief statement of his own views.

The greatest determinant in the formation of rock structure is the ratio of time in the fall of temperature between the

t where the insolubility and crystallizing moment of a com-
nd begins to the increasing viscosity. Suppose a fluid rock
ma, without crystallizations in it, comes to rest and the
perature begins to fall. At a certain point compounds, the
-magnesian ones let us say, commence to separate. The
has been so gradual that only a few centers of crystalliza-
have been set up. The magma retains its fluidity for each
od and each mineral has a considerable time in which to
, orienting and assimilating its substance around it or, to
a phrase, it has a long *crystallization interval.* It is theo-
ally possible that if the conditions are stable for a long
gh period each mineral in turn may exhaust itself in the
ma before the next begins. Usually there are overlaps.
s the process goes on until each has had its turn, the rock
rystallized and the *granular* structure is formed.

ther things being equal, the granularity depends on the
th of the crystallization interval. In the case of the very
eous magmas we must take into account another factor, *the*
sity, which depends greatly on the included water vapor.
is is present in large amount the fluidity of the magma is
mously increased, and with it the radius of action of each
tallizing center, that is, the crystal has a free chance to
, orient material and expand. On the other hand, if there
tle or no water vapor present or it escapes before crystalli-
n begins, the viscosity is greatly increased, the radius of
n of each center is small, and, although the crystallization
rval may be sufficiently long, the crystals are restrained in
growth, new centers are set up and the rock is fine-
ned. Hence we may have coarse granular and fine granu-
ocks without porphyritic structure.*

the case of the basic rocks, the included water vapor has
uch function, their viscosity increases at a vastly slower
for each degree in fall of temperature, hence the radius of
n for equal crystallization intervals is much larger than in
acid rocks and we therefore find them quite coarse granular
r the same conditions which have produced fine-grained
tures in the acid ones. Other things being equal, the
ularity depends on chemical composition, but there is also
it to this, for it also depends on the number of crystalliza-
centers which have been set up.

orphyritic structure.—We can now consider the por-
itic structure. Suppose that an acid magma is injected
included water vapor and that the fall of temperature is
paratively rapid. The vapors escape rapidly and with the
ng and their escape the viscosity augments in a greatly

e also Iddings' Crystallization of Igneous Rocks, Bulletin Phil. Soc.,
ington, vol. xi, p. 105, 1889.

increasing ratio. This means shorter and shorter crystallization intervals for the various components as their periods commence. Thus the earlier ferro-magnesian components may have time to grow to considerable size while the increasing viscosity forces the feldspars and later components to be of very small size. Thus we may have a porphyritic structure with phenocrysts of the monogenetic type as a result of a single process of crystallization. It may be considered a sort of arrested or retarded granular structure.

But phenocrysts of the recurrent type evidently demand a further explanation and this is to be sought in two things. First the writer believes that the influence of mass action is of great importance and that compounds which are present in relatively large or predominant amount tend to set up centers of crystallization before what might otherwise be the proper period for that component. The rest of the process might go on as noted above and a porphyritic structure would be formed with phenocrysts of the recurrent type. Phenocrysts of the recurrent type would then consist of those minerals which are present in largest amount, and this is generally true. Such phenocrysts might form at any time and the earliest would be crystallizing during the whole period and might include the other constituents or exclude and orient them as previously noted.

Second, the writer is inclined to believe that too great regularity in the period of commencing crystallization of the different components has been ascribed to crystallizing magmas. That the different minerals *tend* to have their proper periods is undoubtedly so, but they do not always have them, and, for example, centers of feldspar crystallization may be set up at different times resulting in porphyritic structure as mentioned above. If we dissolve salt in water and allow the solution to crystallize in different beakers, we may obtain under apparently similar conditions a few large crystals, many small ones or a mixture of large and small. The conditions are of course not exactly similar but the differences may be very slight.

The more coarsely granular the rocks are, the more stable, and even the conditions under which they have crystallized and the less likelihood there is for the formation of phenocrysts—yet these do occasionally occur, as noted above in the porphyritic granites. In the fine-grained rocks these conditions are changed, the causes mentioned above become operative and a porphyritic structure is liable to result, as it commonly does.

Thus it seems most reasonable to regard the majority of phenocrysts as formed in place though in some cases they have evidently formed previously while the magma was ascending. Even in these cases they have probably been formed not long before.

Yale University, New Haven, Conn , December, 1898.

r. XXIX.—*On the Occurrence, Origin and Chemical Composition of Chromite;* by J. H. Pratt.

ntroduction.—In a recent paper[*] on the origin of the corun- n associated with the peridotites in North Carolina, ntion was called to the constant presence of the mineral omite in these rocks. During the past summer the occur- e of chromite has been carefully studied and the occur- es in North Carolina have been examined in the field. As sult of these examinations the author has been led to adopt theory that the chromite should be regarded as having been ned at the same time with the peridotite, i. e., as having held in solution by the molten mass of the peridotite and tallized out among the first minerals as the mass began to .

his theory is essentially the same as that advanced by author[†] for the origin of the corundum associated with the dotite rocks, and a similar line of reasoning has been used ubstantiate the theory proposed.

nvestigations concerning the igneous origin of some of the have been materially aided, during the recent years, by able experiments of Morozewicz[‡] and Lagorio[§] and by arches that show us more clearly why we should regard a d mass of rock as a liquid, having similar properties to an nary solution. The fused mass of rock is capable of hold- different minerals in solution and as the molten mass begins ool, these minerals would separate out not according to r fusibility but according to their solubility in the fused s. The more basic minerals being the more insoluble ld be the first to separate out, and as was mentioned in the er already referred to, this crystallizing or solidifying out n the molten mass would take place first on its outer ndaries, for here it would cool first. Convection currents ld tend to bring new supplies of material to the outer zone re crystallization takes place.

ccurrence.—With the exception of alluvial deposits, chro- e has only been found in the peridotite and allied igneous c magnesian rocks, or in the serpentines which have resulted n the alternation of these rocks. In the North Carolina idotites chromite occurs more commonly as scattered grains rystals, but it is also to be found in the form of imbedded ses near the boundaries of the lenticular bodies of dunite.

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[*] This Journal, vol. vi, p. 49, July, 1898.

[†] This Journal, vol. vi, p. 50, July, 1898.

[‡] Zeitschr für Kryst., vol. xxiv, p. 281, 1895.

[§] Ibid., p. 285.

It does not occur in well defined veins, but is often in mas or pockets which apparently have no relation whatever each other. But few writers on the occurrence of chrom have described the relation of the chromite deposits to rock in which it is found. One or two have mentioned chromite as being found near the eastern boundary of the s pentine or at the northern border of the serpentine belt, no definite description of the occurrence could be obtain The large deposits of chromite in North Carolina occur in peridotite rock and near the contact of this rock with enclosing gneiss. Also where there is but a small amount chromite either in small pockets or in grains or crystals, th are more abundant near the contact and diminish in num toward the center of the mass of the peridotite.

Where these large deposits of chromite occur there has b no corundum or but very little found, and where we find large deposits of the corundum there is a scarcity of chrom

This constant occurrence of the chromite in rounded mas of varying proportions near the contact of the peridotite w the gneiss, its occurrence in the fresh as well as in the alte peridotite, indicate that the chromite has been held in solut in the molten mass of the peridotite when it was intruc into the country rock and that it separated out among the f minerals as the mass began to cool.

As has been said, the peridotite (dunite) magma holding solution the chemical elements of the different minerals wo be like a saturated liquid, and as it began to cool the mine would separate or crystallize out, not according to their fusi ity but according to the degree of their solubility in the mol magma. The more basic minerals, according to the general l of cooling and crystallizing magmas, being the less solub would therefore be the first to separate out. These would the oxides containing no silica and in the present case wo be the chromite, spinel and corundum. These minerals wo solidify or crystallize out where the molten magma first beg to cool, which would be at the contact of the mass with country rock; convection currents would tend to bring n supplies of material to the outer boundary which would depo its chromic oxide as chromites. This would account for all irregularities of the chromite deposits: their pocket-like natu the shooting off of apophyses from the main masses of chromite into the peridotite, the widening and pinching of chromite lodes, and the apparently non-relation or connect of one pocket of chromite with another. There has not b enough work done in the North Carolina chromite mines demonstrate the exact position and relation of the chrom deposits to the gneiss or the country rock, and in the descr

of other chromite mines but little light has been thrown
his point.

he chromite would be concentrated near the borders of the
dotite in rounded masses, with offshoots penetrating into
peridotite. The line of contact near the gneiss would be
p and nearly regular, while with the peridodite the con-
would be very irregular.

prospecting for either chromite or corundum the largest
richest deposits may be expected near the contact of the
dotite with the gneiss or other country rock.

hemical composition.—Chromite has been analyzed from
following localities in North Carolina: Price's Creek, six
s southwest of Burnesville, Yancey County; Webster,
son County; and Corundum Hill, Macon County.

ure material for analysis, showing no impurities when
nined with the microscope, was readily obtained by hand
ing.

he mineral was fused several times with bisulphate of
sh, then taken up with hydrochloric acid and silica tested
Iron, aluminium and chromium were precipitated with
nonia, the precipitation being made at least three times.
nesium, calcium and manganese were determined in the
tes by the usual methods.

he precipitate of the mixed oxides was dissolved in hydro-
ric or nitric acid and the excess of acid evaporated. Sodium
roxide was then added in excess and chlorine passed into the
solution. The solution was acidified and the iron and
inium precipitated twice with ammonia and weighed as
ed oxides. These mixed oxides containing a trace of
mium were fused with acid potassium sulphate, digested
water and acidified. One precipitation was made with
nonia to partially remove sulphates. This precipitate was
lved in hydrochloric acid and treated as before, the iron
aluminium being obtained free from chromium. The iron
determined volumetrically.

the filtrates containing the chromium, alcohol and hydro-
ric acid were added and the solution digested for some
. The chromium was precipitated as hydroxide and
hed as Cr_2O_3. To ensure the purity of the precipitate, it
fused with four parts of sodium carbonate to one part of
ssium nitrate, the fusion taken up with water and tested
nagnesium.

number of experiments were made to determine the ratio
rric to ferrous oxide, but they were all unsatisfactory. By
sting the very finely powdered mineral in a mixture of hot
entrated hydrofluoric and sulphuric acid, in an atmosphere
arbon dioxide for half an hour, enough of the mineral was
mposed to show the presence of ferric oxide.

The analyses were made by Dr. Chas. Baskerville[*] and D H. W. Foote.[†]

The result of the analyses were as follows:

	Price Creek.[‡]	Ratio.	Corundum Hill.[‡]	Ratio.	Webster [§]	Rat
Cr_2O_3 ...	59·20	·386	57·80	·377	39·95	·2
Al_2O_3 ...	7·15	·070	7·82	·076	29·28	·2
FeO	25·02	·347	25·68	·356	13·90	·1
MgO	4·42	·111	5·22	·131	17·31	·4
SiO_2	3·20	....	2·80	....	....	..
MnO	·92	....	·69	....	....	..

In the above analyses the ratio of the bivalent oxides to t trivalent oxides is uniformly high and can probably be accounte for by reason that some of the iron calculated as ferrous oxi was in the ferric state, as was proved in the Webster chromit

Taking enough of the Cr_2O_3 and MgO to unite with the Fe and Al_2O_3 respectively to form the molecules $FeO . Cr_2O_3$, a MgO . Al_2O_3, there remains approximately enough of the Cr to unite with the excess of the MgO to form the molecu $MgO . Cr_2O_3$. The nearer the ratio of the bivalent oxid equals that of the trivalent oxides, the nearer the excess of t Cr_2O_3 and MgO equal each other. The inability to determi the ratio of the ferrous to the ferric oxide in the above analys prevents the obtaining of a sharp ratio in the excess of t Cr_2O_3 and MgO.

With the exception of two cases, in all the terrestrial chr mite analyses examined, alumina and magnesium were inva ably present, varying from a small per cent in some samples others that showed the presence of more than 20 per cent these oxides. In the above analyses and in most of the othe examined, it was noticed that the magnesia usually varied wi the alumina, those rich in alumina being correspondingly ri in magnesia.

This constant occurrence of magnesia and alumina in the chr mite would seem to indicate that the molecule of the miner now called chromite is not pure $FeO . Cr_2O_3$ but is a combina tion of the three isomorphous molecules, $FeO . Cr_2O_3$; MgO Cr_2O_3 and $MgO . Al_2O_3$.

But two analyses of chromite (terrestrial) have been foun that do not show the presence of magnesia and alumina, th first a magnetic chrome sand from Chester, Pa., analyzed b T. H. Garrett,[‖] in which all the iron is calculated as ferr

[*] Of the Chemical Laboratory, N. C. Geological Survey.

[†] Of the Sheffield Laboratory, Yale University.

[‡] Baskerville. [§] Foote.

[‖] This Journal, vol. xiv, p. 47, 1852.

de, and the second chromite from Vache Island, West ies, analyzed by J. Clouet.[*]

	I (Garrett).	II (Clouet).
Cr_2O_3	41·55	51·53
FeO	----	48·46
Fe_2O_3	62·02	----
SiO_2	1·25	
	104·82	99·99

greater part of the iron in Garrett's analyses is undoubt- in the form of ferrous oxide, as is indicated by the high cent obtained. From the above, it is seen that a pure omite having the composition $FeO\,.\,Cr_2O_3$ is not common ature.

he $MgO\,.\,Al_2O_3$ occurs nearly pure in nature as normal el. The normal $MgO\,.\,Cr_2O_3$ has not been found in nature, , as indicated from the above analyses, there is good reason elieve that this molecule does exist, and we may expect to normal $MgO\,.\,Cr_2O_3$ occurring as a definite mineral. Under theory of the composition of the chromite, the formulæ the three chromites described in this paper would be as ows:

. Price Creek	$10FeO\,.\,Cr_2O_3$; $MgO\,.\,Cr_2O_3$; $2MgO\,.\,Al_2O_3$.
. Corundum Hill	$9FeO\,.\,Cr_2O_3$; $MgO\,.\,Cr_2O_3$; $2MgO\,.\,Al_2O_3$.
. Webster	$FeO\,.\,Cr_2O_3$; $MgO\,.\,Cr_2O_3$; $2MgO\,.\,Al_2O_3$.

he first two formulæ will represent approximately those of majority of the chromites that have been found, and they approaching the normal chromite $FeO\,.\,Cr_2O_3$ as their limit. s the $FeO\,.\,Cr_2O_3$ molecule decreases and the $MgO\,.\,Al_2O_3$ reases the mineral would approach normal spinel $MgO\,.$ O_3 as its limit, the mineral picotite or chrome spinel being resentative of a mineral near the spinel end.

. E. Wadsworth,[†] in comparing the chromite with the otite associated with peridotites, says:

'It is probable that picotite and chromite belong to the e mineral series, the term picotite being more commonly lied to the freshest states, and that of chromite to those ms more altered, and to the local aggregations arising from migration of the chromic oxide during the alteration of associated peridotite rocks. As a further extreme in alteration a change to a more or less magnetite occurs." ese conclusions are deduced from a microscopical study of se minerals."

Ann. Chim. Phys., vol. xvi, pp. 90-100, 1869; and Wadsworth's Lithological lies, appendix. p. iv.

Lithological Studies, p. 184.

The author does not agree with Dr. Wadsworth that th chromite represents an altered product of a mineral, of whic picotite is a purer form. The chromite is a mineral whic suffers alteration but slightly and, as it is found at the presen time, represents the original mineral and not an altered forn The difference in the microscopical properties can readily b accounted for by the difference in the chemical compositio With an increase in the ratio of the molecule, $MgO . Al_2O$ and a corresponding decrease in the molecule, $FeO . Cr_2O_3$, th more translucent the mineral will become.

These two minerals belong to the same group and are closel allied to each other, and they represent two primary minera and not different stages in the alteration of another mineral.

In the analysis of the Webster chromite, the largest pe centage of MgO was obtained and in the calculation of tl ratios the formula was shown to be $FeO . Cr_2O_3$; $MgO . Cr_2O$ $2MgO . Al_2O_3$, this being the highest ratio of the molecu $MgO . Cr_2O_3$ of any chromite examined. The theoretical con position is here given, together with the analysis of the Webst mineral:

	Webster chromite found.	Theory for $2MgO . Al_2O_3$; $MgO . Cr_2O_3$; $FeO . Cr_2O_3$.
Cr_2O_3	39·95	40·90
Al_2O_3	29·28	30·44
FeO	13·90	10·75
MgO	17·31	17·91
	100·44	100·00

This analysis is similar to that described by Bock* for "magnochromite" from Grochau, Silesia, which containe Cr_2O_3 40·78, Al_2O_3 29·92, FeO 15·30 and MgO 14·00.

In appearance this Webster chromite is different from ar that has come under the author's observation, being much mo of a coarse-grained appearance than ordinary chromite.

In order to designate this Webster chromite and others c similar composition, the author proposes the name, *Mitchellit* in honor of the late Professor Elisha Mitchell of North Carolin

N. C. Geological Survey, December, 1898.

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* Zs. G. Ges., xxv, p. 394, 1873.

RT. XXX.—*The Influence of Hydrochloric Acid in Titrations by Sodium Thiosulphate, with special reference to the Estimation of Selenious Acid;* by JOHN T. NORTON, JR.

ontributions from the Kent Chemical Laboratory of Yale University—LXXX.]

In the method of Norris and Fay[*] for the iodometric deter-
ination of selenious acid, advantage is taken of a direct and
iique action of sodium thiosulphate upon selenium dioxide
the presence of hydrochloric acid. Most excellent results
e claimed for this method; but the explicit statement of the
iginators of the method, that the amount of hydrochloric
id present does not influence the result, provided the titra-
on is made at the temperature of melting ice, is so extraordi-
ry in view of generally accepted ideas in regard to the
teraction of hydrochloric acid and sodium thiosulphate, as to
ggest the necessity of careful investigation of this point.

Pickering,[†] in his investigation of the reaction between iodine
d sodium thiosulphate, has shown that more iodine is required
oxidize the thiosulphate as the proportion of hydrochloric
id increases. He ascribed this effect to the formation of a
lphate, apparently, by the increased activity of the iodine,
t the more rational explanation is that, although some sul-
iate is ultimately formed, the thiosulphate is first partially
composed into free sulphur and sulphur dioxide. Finkener[‡]
d Mohr[§] also mention the decomposing effect of free acid
on sodium thiosulphate.

The sodium thiosulphate used in the following experiments
as taken in nearly decinormal solution and was standardized
running it into an approximately decinormal solution of
dine, the value of which had been determined by comparison
ith decinormal arsenious acid made from carefully resub-
ned arsenious oxide. In the experiments of Table I the
lutions were stirred continuously and kept at a temperature
from 0° to 5° C., while the thiosulphate ran into the acidified
quid. The volume of the solution, though fixed at the be-
nning as given in the table, was considerably increased during
e operation by the melting of the ice. Titrations were con-
icted as rapidly as possible to avoid the separation of sulphur,
hich is likely to occur, especially when the acid and thiosul-
iate are present in large quantities. A perusal of the table

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[*] Am. Chem. Jour., vol. xviii, pp. 703.
[†] Jour. Chem. Soc, vol. xxxvii, pp. 135.
[‡] Anal. Chem., 6 Aufl, pp. 620.
[§] Titrirmethode, 6 Aufl., pp. 279.

shows that the influence of the hydrochloric acid upon the thiosulphate depends chiefly upon the amount of the thiosulphate present and afterwards upon the degree of dilution and its own absolute quantity. Thus when 30$^{cm^3}$ of sodium thiosulphate were employed the effect of 10$^{cm^3}$ of acid is marked at all dilutions within the range of the experiments; the effect of 5$^{cm^3}$ of acid is inappreciable only at a dilution of from 400 to 500$^{cm^3}$, and when 1$^{cm^3}$ of acid is employed the effect is only perceptible at a volume of 100$^{cm^3}$. When 25$^{cm^3}$ of the thiosulphate were used the influence of the acid is less marked; for at a dilution of 500$^{cm^3}$ the effect of 10$^{cm^3}$ of acid is not seen, and 20$^{cm^3}$ of the thiosulphate may be present at any dilution down to 100$^{cm^3}$ in the presence of as much as 10$^{cm^3}$ of the acid, and even considerably more, as experiments not included in the table indicated.

TABLE I.

Volume of liquid at beginning of titration.	$Na_2S_2O_3$ approximately $\frac{n}{10}$ taken.	Volume of $\frac{N}{10}$ iodine used in titration. HCl=none.		=1 cm³.	=5 cm³.	=10 cm³.
cm³.	cm³.	cm³.		cm³.	cm³.	cm³.
100	30	30·25	mean= 30·22	30·75	30·76	31·2
200	"	30·22		30·21	30·56	31·4
300	"	30·20		30·22	31·03	30·9
400	"	30·21		30·20	30·20	30·55
500	"	30·20		30·20	30·21	30·55
100	25	25·29	mean= 25·27	25·32	25·98	25·70
200	"	25·28		25·34	25·40	25·45
300	"	25·29		25·41	25·38	25·83
400	"	25·27		25·24	25·30	25·63
500	"	25·22		25·23	25·40	25·30
100	20	20·15	mean= 20·15	20·17	20·33	20·23
200	"	20·20		20·13	20·27	20·23
300	"	20·21		20·15	20·20	20·17
400	"	20·20		20·10	20·27	20·07
500	"	20·10		20·10	20·17	20·13

The slight discrepancies which appear occasionally in the table were due, no doubt, to unavoidable differences in the time of action.

This influence of time upon the reaction between sodium thiosulphate iodine and hydrochloric acid comes out clearly in the following series of experiments, in which the thiosulphate was run into the acidified water, cooled to a temperature of from 0 to 5° C. by means of ice, the solution being allowed to ıd 5, 10, and 15 minutes. Sulphur was thrown down in rly every case.

TABLE II.

me of the quid at nning of ration.	HCl sp gr. (112) present.	$Na_2S_2O_3$ approximately $\frac{N}{10}$ taken.	Volume of $\frac{N}{10}$ iodine used in titration after standing. 5 min.	10 min.	15 min.
cm³.	cm³.	cm³.	cm³.	cm³.	cm³.
200	10	30	30·80	31·30	32·32
"	"	25	25·50	26·00	26·30
"	"	20	20·30	20·70	20·68

results of the table emphasize sufficiently the necessity of ceeding as rapidly as possible with the titration of sodium sulphate by iodine in presence of hydrochloric acid, when thiosulphate is present in considerable amount. As would xpected, the effect of temperature upon the reaction is also ked. In the following experiments the sodium thiosulte was run into the acidified water, previously heated to temperature indicated, and then titrated with iodine.

TABLE III.

me of id at nning ration.	HCl. sp. gr. (112) taken.	Temp. Centigrade.	$Na_2S_2O_3$ approximately. $\frac{N}{10}$ taken.	Volume of $\frac{N}{10}$ iodine used in titrations at different temperatures.
n³.	cm³.	C.	cm³.	cm³.
00	10	6°	25	23·52
"	"	22°	"	23·73
"	"	34°	"	24·35
"	"	42°	"	24·5
"	"	54°	"	25
"	"	64°	"	26·1

m these results it is plain that the conditions under which siderable amounts of sodium thiosulphate are titrated in sence of hydrochloric acid must be carefully guarded when uracy is a consideration. It is also apparent that in all es the temperature should be reduced as nearly to 0° C. as sible and rapidity of titration by the iodine is an essential. long as the thiosulphate present does not exceed 20^{cm^3} of $\frac{n}{10}$ solution, rapid titration in cold solution proceeds with regularity in presence of hydrochloric acid up to 10^{cm^3} of acid of sp. gr. 112. When, however, the amount of thiosulphate is greater than 20^{cm^3} of the $\frac{n}{10}$ solution, care as to the restriction of the acid and dilution of the solution becomes a necessity. Fortunately, in most analytical processes involving the use of the thiosulphate it is possible to add that reagent from the burette to the solution to be acted upon, so that it is destroyed normally as fast as it is introduced and the danger of interaction with the acid does not occur. In the process of Norris and Fay, however, the method involves the addition of an excess of the thiosulphate to the solution of selenious and hydrochloric acids, and thus the conditions prevail which demand care as to the relation of the acid, the thiosulphate and the degree of dilution. I have experimented, therefore, with this process under varying conditions.

The process of Norris and Fay for the iodometric determination of selenious acid consists briefly in treating the solution of that acid in ice water, in the presence of hydrochloric acid, with an excess of a $\frac{n}{10}$ solution of sodium thiosulphate and titrating back the excess of the thiosulphate with iodine. Four molecules of sodium thiosulphate act, apparently, upon one molecule of selenious acid according to a reaction which the authors propose to study.

The selenium dioxide used was made by dissolving presumably pure selenium in nitric acid and evaporating to dryness. The residue was then treated with water, and a little barium hydroxide was added to remove any sulphate which might be present. The solution was then filtered and the filtrate evaporated to dryness. The residue was mixed with four or five times its volume of dried pulverized pyrolusite, and the whole was put into a porcelain crucible and heated. The sublimate of selenium dioxide was carefully collected on a dry watch-glass and put into a drying bottle as quickly as possible. The pyrolusite prevents any reduction of the selenium dioxide to selenium and the product consisted of beautiful long white needles. This method of preparing the selenium dioxide, which has been used for some time in this laboratory, avoids contamination of the selenium dioxide by nitric acid or water, resulting from the decomposition of the latter, which would be possible in case this reagent were employed in the final sublimation, as is recommended by Norris and Fay. The hydrochloric acid used was of a sp. gr. 112, as recommended by the originators of the process. For the experiments of Table IV the dilution at the beginning was fixed at 400^{cm^3}, and this was increased in every case by the melting of the ice used to cool the liquid. A glance at the preceding part of this paper ll show that at this degree of dilution the hydrochloric acid esent has the least effect.

TABLE IV.

Amount SeO_2 taken. grm.	HCl sp. gr. 112 taken. cm³.	Volume at beginning of titration. cm³.	Excess $Na_2S_2O_3$ employed. cm³.	SeO_2 found. grm.	Error. grm.	
·0616	10	400	2·28	0·0625	0·0009 +	
·0628	"	"	7·11	0·0631	0·0003 +	
·0508	"	"	11·4	0·0511	0·0003 +	
·0587	"	"	12·8	0·0594	0·0007 +	mean
·0807	"	"	15·3	0·0813	0·0006 +	·00005 +
·0633	"	"	20·85	0·0638	0·0005 +	
·0682	25	"	1·11	0·0685	0·0003 +	
·0779	"	"	1.35	0·0788	0·0009 +	
·0465	"	"	18·93	0·0469	0·0004 +	

ese results, while not so good as those obtained by Norris and y, are satisfactory and show that at this degree of dilution the ocess is accurate. These results accord closely with those tained in Table I. At a dilution of 400$^{cm^3}$ or in the prese of only 20$^{cm^3}$ of sodium thiosulphate in excess the drochloric acid present had no perceptible effect. Of course, nust be kept in mind that the hydrochloric acid acts only on the excess of thiosulphate which is not taken up by the enium dioxide. The slight constant plus error in these ults cannot be accounted for by errors in the standards; ey were all carefully determined. Another preparation of enium dioxide was made, starting with pure selenium carely precipitated by sulphurous acid, before putting it through course of treatment previously described, and the results ained by the action of the sodium thiosulphate recorded in ble V agree closely with those of the preceding table.

TABLE V.

	Amount SeO_2 taken. grm.	HCl sp. gr. 112. cm³.	H_2O at beginning. cm³.	$Na_2S_2O_3$ in excess. cm³.	SeO_2 found. grm.	Error. grm.
(1)	·0562	10	400	9·52	·0566	·0004 +
(2)	·0651	25	"	11·20	·0655	·0004 +

ie next step was to determine the effect of diminishing the ution and of varying the strength of acid. The following ole gives the results of my experiments.

TABLE VI.

	Amount of SeO_2 taken. grm.	Volume of H_2O at beginning. cm^3	HCl sp. gr. (112). cm^3	Excess of $Na_2S_2O_3$. cm^3	SeO_2 taken. grm.	Error. grm.
(1)	·1042	200	5	24·16	·1041	·0001 —
(2)	·0611	"	10	13·3	·0611	·0000 ±
(3)	·0850	"	10	21·9	·0828	·0022 —
(4)	·0757	"	25	13·07	·0749	·0008 —
(5)	·0540	"	25	21·02	·0522	·0018 —
(6)	·0674	300	5	10·04	·0679	·0005 +
(7)	·2416	400	5	15·9	·2424	·0008 +

It is apparent that at the dilution of 200$^{\text{cm}^3}$ we run into difficulties, and the greater the excess of thiosulphate present the greater is the error. When the amount of sodium thiosulphate exceeds 20$^{\text{cm}^3}$ a reduction in the amount of acid to 5$^{\text{cm}^3}$ is plainly of advantage, as is shown in a comparison of Exps. (1), (3), and (5), and is not disadvantageous at larger dilutions and with smaller amounts of the thiosulphate, as shown in Exps. (6) and (7). The necessity of placing some limits on the method of Norris and Fay has now, I think, been established. The excess of the thiosulphate must be carefully regulated, as well as the temperature. If one has knowledge of the approximate amount of selenious acid in solution, this is not a matter of great difficulty, and things should be so arranged that no more than 20$^{\text{cm}^3}$ of the $\frac{n}{10}$ thiosulphate should ever be present in excess of the amount necessary to reduce the selenious acid. If this limit —amounting to 0·0400$^{\text{cm}}$ of SeO_2— is placed upon the thiosulphate, so much as 10$^{\text{cm}^3}$ of hydrochloric acid (sp. gr. 112) may be present without endangering the accuracy of the process, provided the solution is diluted to 400$^{\text{cm}^3}$ at the outset; if only 5$^{\text{cm}^3}$ of hydrochloric acid are present, the volume at the beginning may be reduced with safety to 200$^{\text{cm}^3}$. At all events, 5$^{\text{cm}^3}$ of the hydrochloric acid are amply sufficient to bring about the reaction between the thiosulphate and the selenium at any dilution within the range of my experiments. With these precautions taken, the process of Norris and Fay is simple, rapid and accurate; without them, as the experimental results indicate, errors of considerable amount may enter.

According to the method of * Muthmann and Shafer, the determination of selenious acid is effected by the simple addition of potassium iodide to the acidulated solution of selenious

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* Berichte d. d. Chem. Gesell., xxvi, 1008.

id, and the iodine set free is titrated with sodium thiosul-
ate. In this procedure the thiosulphate is taken up by the
line as it is added to the solution, so that the danger of any
ion between the thiosulphate and the acid is out of the
estion. It was shown in a former paper from this labora-
y * that this simple method is inaccurate on account of the
ompleteness of reduction in the cold and in presence of the
line evolved. In a later article also from this laboratory †
was shown that selenium may be completely precipitated
d determined with accuracy gravimetrically provided the
ount of potassium iodide employed is enormously in excess
that theoretically required. This suggests naturally the trial
very large excesses of potassium iodide in the process of
thmann and Shafer. The details of experiments made in
s manner are given in the following table.

TABLE VII.

	SeO_2 used. grm.	KI. grm.	Vol. of solution. cm^3	HCl sp. gr. (112). cm^3	SeO_2 found. grm.	Error. grm.
(1)	·0553	10	150	10	·0558	·0005 +
(2)	·0574	5	"	"	·0567	·0007 —
(3)	·0683	5	"	"	·0683	·0000 ±
(4)	·0487	5	"	"	·0484	·0003 —
(5)	·2617	10	"	"	·2589	·0028 —

is obvious that for small quantities of selenium dioxide the
uracy of the process is very much increased by the use of
ge amounts of iodide, though, of course, the difficulty in
ding the end reaction due to the presence of precipitated
selenium still remains; but the process is still inaccurate
en large amounts of selenium dioxide are employed.

In conclusion I wish to thank Prof. F. A. Gooch for his
d advice and assistance.

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* This Journal, Gooch and Reynolds, vol. l, 254.

† Peirce, this Journal, vol. i, 1896, p. 416.

ART. XXXI.—*Some Rock-forming Biotites and Amphiboles*

by H. W. TURNER, with analyses by W. F. HILLEBRAN
H. N. STOKES, and WILLIAM VALENTINE.

THE minerals referred to in this paper were separated fro the rocks containing them by means of the Thoulet solutio The analyses were made in the laboratory of the U. S. Ge logical Survey, the object being to furnish a basis for calcula ing the molecular composition of the rocks containing ther All of the material was fresh and sensibly free from foreig particles. The powder analyzed in each case was examine microscopically and such impurities as were found are give Samples of minerals as well as chips of the rocks containi them will be sent to any one who is investigating rock-formi minerals, upon request. The specimens came from the Sier Nevada in all cases.

Biotite.

Biotite No. 2136 is from the biotite-granite at the base of Capitan in Yosemite Valley. It is quite black in color, as se with a hand lens, but under the microscope is brown. Th biotite-granite forms large areas in the granitic complex of t Sierra Nevada, and is quite uniform in appearance and comp sition at nearly all points where I have seen it. The bioti which it everywhere contains as an essential constituent, quite the same in color and degree of pleochroism in the ma thin sections examined, and the analysis given below may fairly assumed to represent in general the composition of t biotite of this granite. Biotite-granite 2136 contains quartz plagioclase>orthoclase> biotite> magnetite> titanite>apati >zircon, the last four minerals being merely accessories. Th aplitic granites that cut the other granites in dikes likewi contain a very similar biotite in small amount.

A microscopic examination of the material analyzed, as well the mere fact that phosphorus pentoxide is present, showed th there were apatite prisms mixed with the biotite. The analys was therefore recalculated and the P_2O_5 (·20) taken out togeth with the CaO (·26) required by the P_2O_5 to form apatite. Th H_2O below 110° C. is likewise left out in this recalculatio since it was no doubt adventitious.

Biotite No. 1751 S.N. is from a quartz-monzonite collecte about 1 klm. southwest of Blood's Station, Alpine County, i the Big Trees quadrangle. The material analyzed was foun on microscopic examination, to contain occasional white grain

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[*] Published by permission of the Director of the U. S. Geological Survey.

	Biotite 2136.	2136 recalculated.	Biotite-granite 21·36.	Biotite 1751.	Quartz-monzonite 1751.	Biotite 1743.	*Gneiss 1743.*	*Biotite 2652 S.N.*
SiO_2	35 64	36·02	71·08	35 62	66·91	36·62	*51·5*	35·75
TiO_2	1·12	1·13	·22	2·61	......	3·03	....	3·16
ZrO_2	....	....	·08	....	......	......	....	none
Al_2O_3	18·62	18·81	15·90	15·24	......	14·37	....	14·70
Cr_2O_3	....	....	....	....	......	......	....	trace
V_2O_3	....	....	....	....	......	......	·08	·05
Fe_2O_3	5·54	5·60	·62	4·69	......	4·04	....	4 65
FeO	14·60	14 75	1·31	13·67	......	17·09	....	14·08
MnO	·79	·80	·15	·74	......	·40	....	·45
NiO and CoO	....	....	....	....	......	......	....	·02
CaO	·90	·65	2·60	·95	3 51	1·48	....	·17
SrO	none	none	·02	trace	......	trace	....	?
BaO	trace	trace	·04	·26	......	·33	....	·12
MgO	9 72	9 82	·54	12·70	......	9·68	....	12·37
K_2O	9·22	9·32	4·08	7·72	3·13	8·20	....	9·19
Na_2O	·38	·38	3·54	·50	3·59	·45	....	} ·32
Li_2O	trace	trace	trace	trace	trace	trace	....	
H_2O below 110° C.	·48	....	none	·94	......	·90	....	1·03*
H_2O above 110° C.	2·54	2·57	·30	4·36	......	3·26	....	3·64*
P_2O_5	·20	....	·10	none	......	none	....	·03
SO_3	....	....	none	....	......	......	....	......
Cl	....	....	·02	....	......	......	....	......
F	·26	·26	CO_2 trace	none	......	·10	....	·17
Total	100 01	100·11	100 60	100·00		99·95		99·90
Oxygen = F.	·11	·11				·04		·07
	99·90	100·00		100·00		99·91		99·83
Analyst	Valentine		Valentine	Valentine	Stokes	Valentine	Hillebrand	Hillebrand

* Determined at 105° C.

probably feldspar. The impurities, however, form such a minute portion of the material that the analysis may be considered as sufficiently correct for use in calculating the constituents of the granitic rock of which it forms a part. The mica is quite black in color, as seen with a hand lens. Under the microscope it is a darker brown than the biotite of the biotite-granite. This biotite is characteristic of the granodiorite and quartz-diorite series, and of the quartz-monzonite. It contains more magnesia than any other of the biotites analyzed but nearly the same as amphibole 2652, also from quartz-monzonite. Dr. Hillebrand examined specimen 1751 and the biotite from it for vanadium. He found that the rock contained ·012 per cent of V_2O_3 and the biotite ·066 per cent. Quartz-monzonite 1751 is composed of plagioclase>quartz>orthoclase>biotite>amphibole. There are present as accessories titanite, apatite, and iron ore.

Biotite No. 1743 S.N. is from a pyroxenic gneiss from the south bank of the North Mokelumne River, about 1 klm. up stream from the mouth of Bear River, in the Big Trees quadrangle. The material analyzed was found, on microscopic examination, to contain occasional grains of amphibole, but these probably do not sensibly affect the result. This biotite is reddish-brown in color and quite similar to the biotite so often found in contact metamorphic rocks. Dr. Hillebrand subsequently tested the material for vanadium and found gneiss 1743 contained ·08 per cent V_2O_3, and the biotite from it ·127 per cent. Gneiss 1743 is composed of plagioclase, reddish-brown biotite, greenish-brown amphibole, quartz, pyroxene, titanite, magnetite, apatite, and pyrrhotite, the relative abundance being approximately indicated by the order in which the constituents are enumerated.

Biotite No. 2652 is from a quartz-monzonite from a block by the Tioga road southeast of Mt. Hoffmann in the Mt. Dana quadrangle. The amphibole 2652 analyzed is from the same block, and both were separated as well as analyzed by Dr. Hillebrand. The block above referred to was far richer in amphibole and biotite than is usually the case with the quartz-monzonite of the region. There is thus a possibility that these minerals may differ somewhat in composition from the same minerals where they occur evenly distributed through the magma. An examination of the powder analyzed shows on one slide a very few foreign particles, namely, apatite and amphibole. The apatite should of course be deducted from the analysis as well as the water below 105° C. Dr. Hillebrand found that the mica contains no rare earth, zinc, or metals of the H_2S group. The specific gravity of biotite 2652 at 21° C. is 3·05. Quartz-monzonite 2652 was not analyzed, but for

rposes of comparison No. 2179, given in the table of
aphibole analyses, may be substituted, as this is from the
me area and represents the average rock.

A comparison of the biotite analyses given in the table with
ose of the rocks from which the micas were obtained, does
t suggest any very definite relations. These micas are all
ite similar in composition. It may be noted, however, that
e biotite richest in alumina and alkali is from the most acid
ck of the series, the biotite-granite (No. 2136). This rock
ntains no amphibole. Biotites 1751 and 2652 are richer in
ıgnesia. Both of these are very similar in composition as
ell as in color and pleochroism, and both of them are asso-
ıted with amphibole.

Analyses of Amphibole and the containing rocks.

	Amphibole 1970	Gabbro 1970.	Amphibole 2652.	Quartz-monzonite 2199.	Amphibole Donegal granite.	Donegal granite.
....	46·08	47·27	47·49	66·83	47·25	58·04
....	·77	·92	1·21	·54	......	......
....	......	......	none	·04	......	......
....	10·56	20·82	7·07	15·24	5·65	16·08
....	......	faint trace*	......	......	......	......
....	......	·02	·04	......	......	......
....	2·81	1·85	4·88	2·73	19·11	8·27
....	8·30	4·26	10·69	1·66	·94	0·45
....	·15	trace	·51	·10	1·70	1·12
CoO	......	none	·02	......	......	......
....	12·64	13·02	11·92	3·59	11·76	6·52
....	none	trace	none	·03	......	......
....	none	none	none	·11	......	......
....	14·40	6·44	13·06	1·63	11·26	2·94
....	·34	·22	·49	4·46	1·04	2·21
....	1·62	2 75	·75	3 10	·98	4·65
....	none	none	trace	trace	......	......
w 110° C...	·17	·08	†	none	......	......
e 110° C...	1·97	1·27	1·86	·56	......	......
....	·18	·74	none	·18	......	......
....	......	none	......	trace	......	......
....	......	·20	......	......	......	......
....	......	......	......	none	......	......
....	......	trace	......	·02	......	......
....	none	......	·06	......	......	......
....	99·99	99·86	100·05	100·82	99·69	100·28
....	Valentine	Stokes	Hillebrand	Valentine	Haughton	Haughton.

An examination of the powder of amphibole 1970 shows
at it contains a few grains of labradorite but otherwise appears

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* Cr_2O_3 and V_2O_3 determined by Dr. Hillebrand.

† Dried at 105° C. before analyzing. No rare earths or zinc present.

to be quite pure. The phosphorus pentoxide (P_2O_5) show
in the analysis must, however, be ascribed to apatite, and th
should be deducted from the amphibole analysis together wi
a corresponding amount of lime. In addition minute blac
grains may be noted in the amphibole itself. These are pro
ably magnetite, but the amount thus included must be sma
since the powder was treated with an electro-magnet and t
more highly magnetic grains removed. No titanite or oth
titaniferous mineral were found in the thin sections of gabb
1970 or in the amphibole powder. The titanic oxide (TiO
shown in the analysis therefore probably belongs to the amph
bole. The pleochroism is strong in brown and greenish brow
colors with large extinction angle.

Amphibole-gabbro 1970 is from Beaver Creek about 18 kl
east of Big Trees P. O. in the Big Trees quadrangle. It
composed chiefly of labradorite and amphibole but contains
little pyrite and pyrrhotite.

Amphibole 2652 is exceptionally pure. It is pleochroic
dark green tints with large extinction angle. There are som
minute black grains included in the amphibole. These a
probably magnetite. One foreign particle only was noted in
slide of the powder. As before stated, this amphibole com
from the same block of quartz-monzonite as biotite 265
The specific gravity of amphibole 2652 at 21·5° C. is 3·20
Analysis 2179 is that of an average quartz-monzonite of t
region. It is well known that the metasilicates of rocks ri
in alkalies are sometimes themselves rich in alkali. This relati
does not appear to obtain in the case of amphiboles 1970 a
2652, the former of which comes from a basic rock poor
alkali, and the latter from an acid rock rather rich in alka
yet there is more alkali in the amphibole from the basic th
in that from the acid rock.

There is also added to the table an analysis of an amphibo
from the Donegal granite* as well as one of the granite itse
It is evident from the analysis of this granite that the rock
really a quartz-diorite or granodiorite and not a true granit
The biotite from the Donegal granite is remarkable for t
very high content of ferric iron—19·11 per cent.

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* Haughton, Quart. Jour. Geol. Soc. Lond., vol. xviii, 1862, p. 416.

RT. XXXII.—*On one little known and one hitherto unknown species of Saurocephalus;* by O. P. HAY.

THE fish *Saurocephalus lanciformis* was first described and amed by Dr. Richard Harlan in 1824.[*] This description and ie accompanying figures were reprinted in 1835 in the same ithor's Medical and Physical Researches.[†] The specimen on hich the genus and species were based had been collected oout twenty years previously, by Lewis and Clark, at some cality probably in northeastern Nebraska. It consisted of ie greater portion of the left maxilla; but was described by (arlan as belonging to the lower jaw. He also regarded it as aving belonged to a reptile allied to *Ichthyosaurus.* Louis gassiz first recognized the ichthyic nature of the remains[‡] lthough he confounded them with an entirely distinct species); and his conclusions were confirmed by Richard Owen.[§] r. Leidy[‖] corrected Agassiz's errors, and gave more accurate escriptions and figures of the maxillary than had been furished by Harlan.

No remains of Harlan's species, other than the maxillary eferred to, have hitherto been described. Dr. E. W. Hilgard[¶] as reported the species as occurring in the Vicksburg group the Eocene, but the identification was undoubtedly erroeous. Dr. William Spillman[**] has also included this species his list of fossils belonging to the Tombigbee greensand of ie Cretaceous at Columbus, Miss. Although this identificaon is less improbable than the former, we have nothing to onfirm its correctness.

Notwithstanding the scantiness of the material belonging to ie type species, our knowledge of the genus *Saurocephalus* as been greatly increased through the descriptions of closely elated and more perfectly preserved species. For this addional knowledge we are indebted to Cope and Newton, and iore recently to Alban Stewart, of the University of Kansas.

For some time I have had in my possession some remains hich on examination prove, in my judgment, to belong to (arlan's species. This material was collected for me in the egion of Butte Creek cañon, south of Wallace, Kan.; and ie horizon is undoubtedly that of the Niobrara Cretaceous. (y material consists of both the mandibles, the right maxilla, ie pterygo-palatine arch and a few other bones.

The maxillary (fig. 1) is rather short and deep. The portion elonging in front of the palatine condyle is missing; but the ondyle itself is present. The alveolar border is somewhat curved, and is occupied by compressed sharp-edged teeth. O these there are present twenty-eight; but if we restore th bone, as we can safely do, I believe, by aid of Stewart's figure of *S. dentatus*,[*] we may conclude that there were originall thirty-four teeth, possibly one or two less. The root of th most anterior tooth has been exposed by the fracture, and it fang is seen to be distinctly faceted; so that it presents jus such an appearance as the tooth of *S. lanciformis* figured b Leidy.[†] The roots of teeth situated more posteriorly whos fangs have been exposed by a tool are similarly faceted. Cop states[‡] that *S. lanciformis* is to be distinguished from his S *arapahovius*, by the lack of facets on the roots of the teet of the latter.

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[*] Jour. Acad. Nat. Sci. Phila. [1], iii, pp. 331–337, pl. xii, figs. 1–5.

[†] Med. Phys. Res., pp. 362–366, pl., figs. 1–5.

[‡] Poiss. Foss., v, p. 102.

[§] Odontography, p. 130, pl. 55.

[‖] Trans. Amer. Philos. Soc., 1857, xi, pp. 91–95, pl. vi, figs. 8–11.

[¶] Report Geol. and Agric. Mississippi, 1860, p. 142.

[**] Op. cit., p. 389.

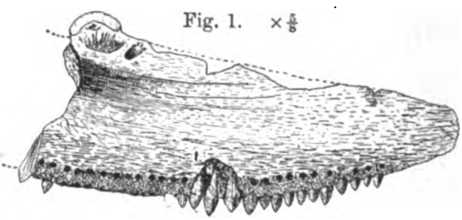
Fig. 1. × 5/8

Leidy estimated that the maxilla in his hands had supporte only twenty-six or twenty-eight teeth, and he was probabl correct. That maxilla, a larger one than the one in my possession, seems to have been broken just behind the palatine condyle. If now we take from Leidy's drawing the width of th bone at this point and apply it to the alveolar border, we fin that it includes ten teeth; the width of my own specime includes thirteen teeth. It is not impossible, however, that th specimen figured by Leidy had been broken away some littl distance behind the condyle. At any rate, I do not believ that the difference of a few teeth, other things being alike would justify us in regarding the specimens as belonging t different species.

As in the case of the original specimen there is a shallo groove running along the mesial surface of the maxilla, abou 5^{mm} from the alveolar border, and from this groove foramina one for each tooth, enter the bone.

Depth of maxillary at palatine condyle	38^{mm}
Distance from anterior end of palatine condyle to hinder end of maxillary	85^{mm}

The right mandible is shown in fig. 2, five-eighths the natural size and showing the mesial surface. The alveolar borde is straight and supports thirty-four teeth, of which those occupying the middle of the border are the largest. In general they are larger than the teeth of the upper jaw. The lin which spans thirteen teeth in the maxilla spans ten in the dentary. At the proximal end of the mandible there must have been a process of the dermarticulare, as in related forms; but in the specimen figured it is hidden by the overlying ceratohyal, which is not shown in the figure. At the anterior end of the mesial face of the dentary there is found a broad surface, rough with processes and pits, an indication that the two dentaries were strongly bound together. The extreme anterior end of each dentary is occupied by a surface to which was evidently attached such a predentary as Stewart has described as belonging to several related species. A groove and a row of foramina are present on the median face of the dentary.

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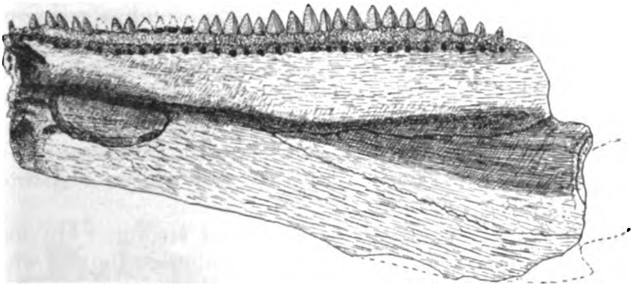
[*] Kan. Univ. Quart., vii, p. 25, pl. i, figs. 3*a*, 4*a*.

[†] Trans. Amer. Philos. Soc., xi, pl. vi, fig. 9. [‡] Cretaceous Vertebrata, p. 216.

Fig. 2. $\times \frac{5}{8}$



Length of alveolar border	112^{mm}
Length of mandible from cotylus	130
Depth of mandible at last tooth	56
Depth of mandible at symphysis	34

Fig. 3 represents, five-eighths the natural size, the pterygopalatine arch seen from within. A triangular piece is missing from the anterior end, and the lower end of the ectopterygoid, *pg*, is defective. As I interpret the bones, the arch is remarkable for the large size of the palatine, *pa*. While the sutures which are represented in the figure are very distinct, I am wholly unable to find one separating the entopterygoid, *ep*, from the metopterygoid *mt. pg.* On the upper border of the

Fig. 3 $\times \frac{5}{8}$

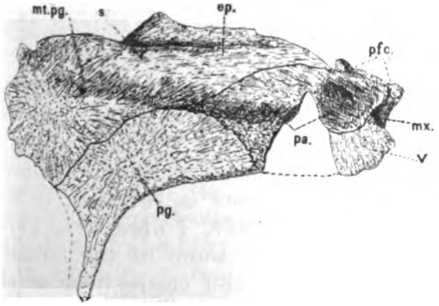
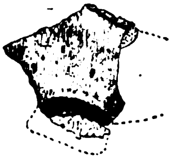


Fig. 4. $\times \frac{1}{2}$



arch, at the point indicated by the line *s*, there appears to be an indication of a suture. If such it is, it probably extends downwards to a point near the hinder end of the palatine. The arrangement of the bones is quite different from that found by myself in *Xiphactinus*.*

At the lower border of the anterior end of the palatine there is a broad surface, *v*, which was probably in contact with an articulating surface on the vomer. The notch seen in the anterior end is occupied by another articulatory surface, *mx* for the anterior palatine condyle of the maxilla. The anterior end of the upper border furnished an articulation, *pfc*, with the prefrontal, but this is elongated and rough, not broad and smooth, as it is in *Xiphactinus*.

Anteriorly the palatine is thick and strong. On its outer surface this portion is finely vermiculated above, while the lower portion furnishes a concave articulation for the condyle of the maxilla. The general appearance of this portion may be seen from fig. 4, which represents the palatine of the next species. Below the concave surface for the palatine condyle of the maxilla there is seen a broad rough surface which must have been applied to the inner face of the maxilla. The greater portion of this is wanting in the specimen shown in fig. 4. Its limits are indicated by the dotted line. On the outer face of the metapterygoid, from the highest point seen in fig. 3 there runs downward and backward a sharp ridge which evidently bounded the orbit below. The portion of the metapterygoid above and mesiad of this ridge formed the floor of the orbit. This indicates that the orbit was placed well backward. I find no satisfactory evidences of the presence of teeth on the pterygoid and palatine bones. If we shall add to the maxillary the probable antero-posterior extent of the premaxillary, we shall find that it is approximately equal to the length of the lower jaw. Hence the latter did not project beyond the upper jaw as it did in the case of those species which Stewart has referred to the genus *Saurodon*.

Two characters seem to distinguish *Saurodon* from *Saurocephalus*, viz.: the presence of notches, instead of foramina, for the successional teeth and the projection of the lower jaw beyond the snout of the fish. I have been inclined to believe that the presence of these two characters is sufficient to distinguish *Saurodon* as distinct. However, I observe in some specimens of this supposed genus that some of the notches become closed into foramina; and we can easily imagine all gradations between notches and foramina high above the alveolar margin. Moreover, it is probable that the other character will fail. Recently Mr. Stewart† has published figures, without description, of remains which he refers to Cope's *Sauro-*

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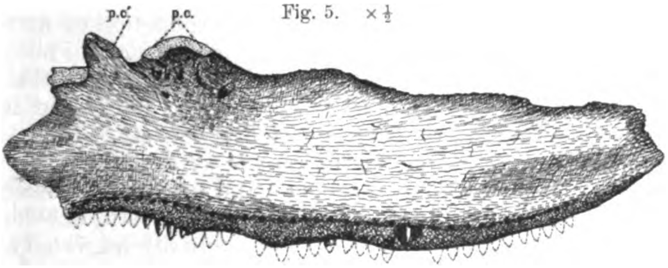
* Zoolog. Bull., ii, 1898, p. 39, fig. 7.

† Kan. Univ. Quart., vii, pl. xvi, figs. 4, 5.

n phlebotomus. Mandible and maxilla are shown. Measure-
ents show that the maxilla, without the premaxillary, is
arly as long as the alveolar border of the mandible, so that
is almost certain that in this species there was no projection
the dentary beyond the snout. It seems probable therefore
at *Saurodon* must be abandoned.

I present here (fig. 5) the right maxilla and the premaxillary
g. 4) of another species of *Saurocephalus*, which I regard as
t undescribed. It is especially distinguished from described
ecies by its elongated maxillary bone. To illustrate this, I
npare it with Mr. Stewart's *S. dentatus*, which is itself a
ecies with a rather long maxilla. In *S. dentatus* the total

Fig. 5. × ½



gth of the maxilla is 142^{mm}, its height at the palatine con-
le $48 \cdot 5^{mm}$. My specimen has the same height at the condyle;
t the total length is 172^{mm}, a difference of 30^{mm}, equal to 21
r cent of the shorter maxilla. My species, therefore, prob-
ly had a relatively slender head and a larger mouth than had
dentatus.

In the maxilla figured I count alveoli for thirty-seven teeth;
t in the maxilla of the other side, somewhat broken, the
eth extend backward somewhat farther; so that there must
ve been forty. At some time in the career of its owner the
ht maxilla has been fractured obliquely across its middle,
d this accident has affected the neighboring teeth. One of
ese has thus become exposed nearly half-way to the tip of
e fang. This exposure reveals the fact that the fang is
eted, as it is in *S. lanciformis.* The great length of the
axilla distinguishes this species from both *S. lanciformis* and
dentatus, and the facets on the teeth distinguish it from
pe's *S. arapahovius.* Mr. Stewart has not described the
ndition of the fang of the teeth of his *S. dentatus.*

In fig. 5 *p. c* represents the palatine condyle; *p. c'*, the
terior palatine condyle which was applied to a surface like
at shown in figure 3 at *mx.*

I propose to call the fish above described *Saurocephalus*
*mphagus.**

* Inde ruunt alii rapida velocius aura,
Pamphagus et . . . . . .
Ovid, Met., Bk. iii, l. 209.

It has been supposed that the foramina, situated one opposite each tooth and on the mesial face of the maxilla and of the dentary, are for the transmission of nerves and vessels to the teeth. Richard Owen* seems not to have so regarded these foramina. He believed that they "lead to the cavities containing the germs of the successional teeth." The latter probably began their development in, or at the bottom of, these foramina but they soon passed more deeply into the bone. In fig. 1 at there is found a developing tooth whose tip is on a level with the row of foramina: but its root extends high up into the bone. Nerves and vessels entering the tooth by way of the foramina alluded to would have to take a very tortuous course The functional tooth immediately below the young tooth figured seems already to have suffered some reduction of its fang

The germs of the teeth of the *Saurocephalidæ* did not gain a lodgment in the bones of the jaws in the same way that the teeth of the higher vertebrates did. In the latter the fangs were first planted in grooves in the dental borders of the bones and we must suppose that these grooves, at first shallow, have in successive generations, deepened and become portioned of to form sockets. In the *Saurocephalidæ* the teeth, developing originally on the dental border, have gradually migrated away from this border, on the mesial face of the supporting bones and, by means of the foramina described above, have made their way through the mesial wall of the sockets. The notches found in the species referred to *Saurodon* show the earlies stages of this migration.

The distinguished palæo-ichthyologist, Mr. A. S. Woodward has recently kindly called my attention to a suggestion made by Prof. E. D. Cope that the *Saurocephalidæ* are closely related to the *Chirocentridæ*, represented by the large *Chirocentrus dorab* of the Chinese and Indian seas. I have unfortunately had no opportunity to study a skeleton of this fish; but judging from the figures of the fish found in Cuvier and Valenciennes, pl. 565, and in Day's Fishes of India, pl. clxvi fig. 3, its external appearance must be much like that of the extinct *Xiphactinus*. Nevertheless, we have no intimations that the teeth of *Chirocentrus* are fixed to the jaws in any way different from those of ordinary fishes. The fixation of the teeth in sockets is an unusual thing among fishes; and this character alone, it appears to me, is sufficient to remove *Xiphactinus* and its allies from the Chirocentridæ, although not necessarily to a great distance. I suspect that the *Saurocephalidæ* will, when they are better known, show distinctive characters in the vertebral column also.

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* Odontography, p. 131.

ART. XXXIII.—*A Study of Some American Fossil Cycads.* Part II. *The Leaf Structure of Cycadeoidea;* by G. R. WIELAND. (With Plate VII.)

Introduction.

IT is generally conceded that the Cycads culminated in the Jurassic, and formed the principal plant life of that time. Nevertheless, the abundant and widely distributed fossil remains of this vegetation consist almost entirely of disconnected and scattered trunks, leaves, and occasional fruits, which have been described under separate generic and specific names. So uniformly is this true that Count Solms-Laubach[9]* mentions an individual of *Zamites gigas*, Morr., from the upper Jurassic sandstone of Yorkshire, England, as the only cycad known to him, whose stem with the leaves attached may be identified with certainty. This specimen, now in the Paris Museum, is figured by Saporta,[4] and in leaf and habit is said to recall *Stangeria* most nearly.

There has, therefore, been no sufficient means of correlating the various genera and species founded on isolated parts,—a fact which now makes especially important a determination of both trunk and leaf characters when united in a single individual. For this reason it is fortunate that not only the leaf and its prefoliation, but also the accompanying floral characters, may be completely determined in a number of the unusually perfect cycadean trunks now in the Yale collection, though but a single one is considered in this paper.

Prefoliation of Cycadeoidea.

The subject of the present, as well as of the preceding, preliminary study is afforded by the type specimen of *Cycadeoidea ingens*, Ward, a photograph of which has been already given. As previously mentioned, this fine male trunk bears on its summit, above the series of flower buds, a crown of young leaves imbedded in fine scales, or ramentum. It would seem that, having formed its blossoms, this cycad was again preparing to put forth its energies in the unfolding of an additional series of leaves, about twenty in number. Happening to be fossilized at such a critical time in its life, under the most favorable conditions, there has been preserved a wealth of characters scarcely equalled by any Mesozoic plant of which there is a record. This specimen alone affords all the material required for a restoration.

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* The numbers refer to the list of papers given in Part I of these studies. This Journal, March, 1899, pp. 219–226, Plates III, IV.

A careful examination of the summit of the trunk showed tha as found in the field, it had been subjected to the erosive actio of sand-laden winds which had partially exposed several tran verse sections of the tips of young leaves. It was found tha these belonged to a circularly placed series just ready to emerg at a distance of from 5 to 8 cm from the apex. Several pairs o these leaves enveloped in ramentum were removed for study and the disposition of their parts with reference to the trun determined from longitudinal, transverse, and tangentia sections.

As so removed, each rachis with its attached pinnules forme an erect subcylindrical, or spindle-shaped, body, 6 cm i length, with a long diameter of 15 mm coinciding with th radius of the trunk, and a short diameter of 12 mm at righ angles to it. The rachis was erect and situated distally on th long diameter. It bore the pinnules inclined inwards in tw imbricating ranks, formed by the two rows of pinnæ on eac leaf, in such manner that their upper surfaces all faced toward the axis of the trunk.

A clearer perception of the arrangement of the pinnule with respect to the rachis and the trunk may be had if a ordinary, expanded, young *Zamia* leaf is considered in it natural position on the summit of the trunk. If the pinnule of such a leaf are folded toward the axis of the trunk in tw ranks, and these ranks are brought together side by side, th position of the parts in the unexpanded young leaf of *Cycadeoidea* will be paralleled. As just stated, it at once become apparent that the rachis is farthest away from the trunk, an that the upper side of each pinnule faces the axis of the trun This is also the relative position of the parts in the unexpande young leaf of *Zamia*. *Cycadeoidea* thus had the direct mod of prefoliation characterizing the existing North America cycads *Zamia* and *Dioön*.

The Cycadeoidean Leaf Structure.

While an exhaustive treatment of the anatomy of thes leaves must be deferred for the present, the features of mor immediate interest may be here described.

The exact arrangement of the pinnules and of their fibro vascular bundles is shown in the transverse section, figure (Plate VII), and in the longitudinal section, figure 3, th general position of these sections being indicated in figure 1.

The transverse section, figure 2, shows that, just above th termination of the rachis, there are 20 pairs of projecting pinnules. Since the pinnules nearest the rachis must necessaril be cut through their bases, while in a given transverse section those farthest from the rachis must be cut through their tips (as may be understood by referring to figure 1), this transverse section virtually represents a series of sections such as would be obtained if a single pinnule were cut transversely 20 times at regular intervals from base to tip. Nearer the base of the leaf, a transverse section cuts 34 pinnules. As there are about 20 insertions of pinnules above this basal section, and apparently no pinnules lying wholly beneath it, there are approximately 60 pinnules in all. The rachis and pinnular insertion have not yet been studied.

The principal fact of interest shown by the longitudinal section represented in figure 3 is the emergence of leaf tips on the side next the axis, or rachis, of the leaf. As this section is wholly above the termination of the rachis, this emergence indicates that the topmost pinnæ are relatively short. Necessarily, then, the leaf at this stage of its growth was of a somewhat truncate form.

This fact, however, does not permit surmise as to the exact leaf habit of *Cycadeoidea*, for subsequent growth either may have increased the truncation, or, because of great elongation of the rachis, resulted in a lanceolate leaf. Presumably the study of the prefoliation and subsequent development of the rachis and pinnæ of living cycads, especially *Zamia*, will indicate what must have been the appearance of the full-grown leaf of *Cycadeoidea*.

The microscopic structure of the pinnules is partially shown in figures 4 and 5. In figure 4 is shown a transverse section through a pinnule cutting a fibro-vascular bundle. The structure of the relatively heavy epidermis of the upper side of the pinnule is not distinct even in this young stage, and forecasts a dense and stiff structure. A single layer of sclerenchyma cells of rounded section forms the hypodermis, from which a double row of similar cells passes in confluently to the bundle, where it divides to form a more or less complete circular row of sclerenchyma cells enclosing the phloem and xylem. The uniformity of this arrangement gives the transverse section of the bundles a characteristic flask-shape. Beneath the hypodermis is a distinct layer of palisade parenchyma followed by an indistinct one grading into the rounded parenchyma cells occupying the space between the bundles. The lower portion of the leaf, or that beyond the bundles, is composed of well-defined spongy parenchyma, with distinct intercellular spaces, and is bounded by a thin epidermis, the structure of which is not well marked. The lower surface at this stage is somewhat glabrous, although revolute margins are apparently indicated.

In figure 5 is shown a longitudinal section through the palisade parenchyma and bundle connection, with the hypodermis. This section displays clearly the usual dichotomous cycadean venation, as well as the mode of bundle increase. The pinnæ are of linear-lanceolate form, and without a distinct midrib.

A comparison of these structures with those of *Zamia integrifolia* shows a striking resemblance in all essential characters,—a resemblance that is even more marked than is that between the pinnæ of *Zamia* and of some of the other existing genera of the *Zamiaceæ* (*Zamiæ*).

The character of the ramentum surrounding these leaves remains to be briefly mentioned. It consists of thin scales, or hairlike forms, composed of stringy elements, and strongly resembles the ramental cells figured by Carruthers[9] and Seward[10] in their respective descriptions of *Bennettites Gibsonianus* and *Cycadeoidea gigantea.* A transverse section of the ramentum is shown in figure 6. The flat sides of these scales quite uniformly face the leaves, though as such a large portion of the summit is occupied by a mat of relatively the same character, it is probable that much of this hairy and scaly material is borne on the trunk in the space intervening between the petioles of the young leaves.

Yale Museum, New Haven, Conn., March 20, 1899.

EXPLANATION OF PLATE VII.

FIGURE 1.—Diagram of a hypothetical leaf, with a reduced number of pinnules, showing the position of the sections represented in figures 2 and 3. *O*, *O'*, are in the plane of the transverse section, figure 2, and also approximately mark the base of the longitudinal section, figure 3.

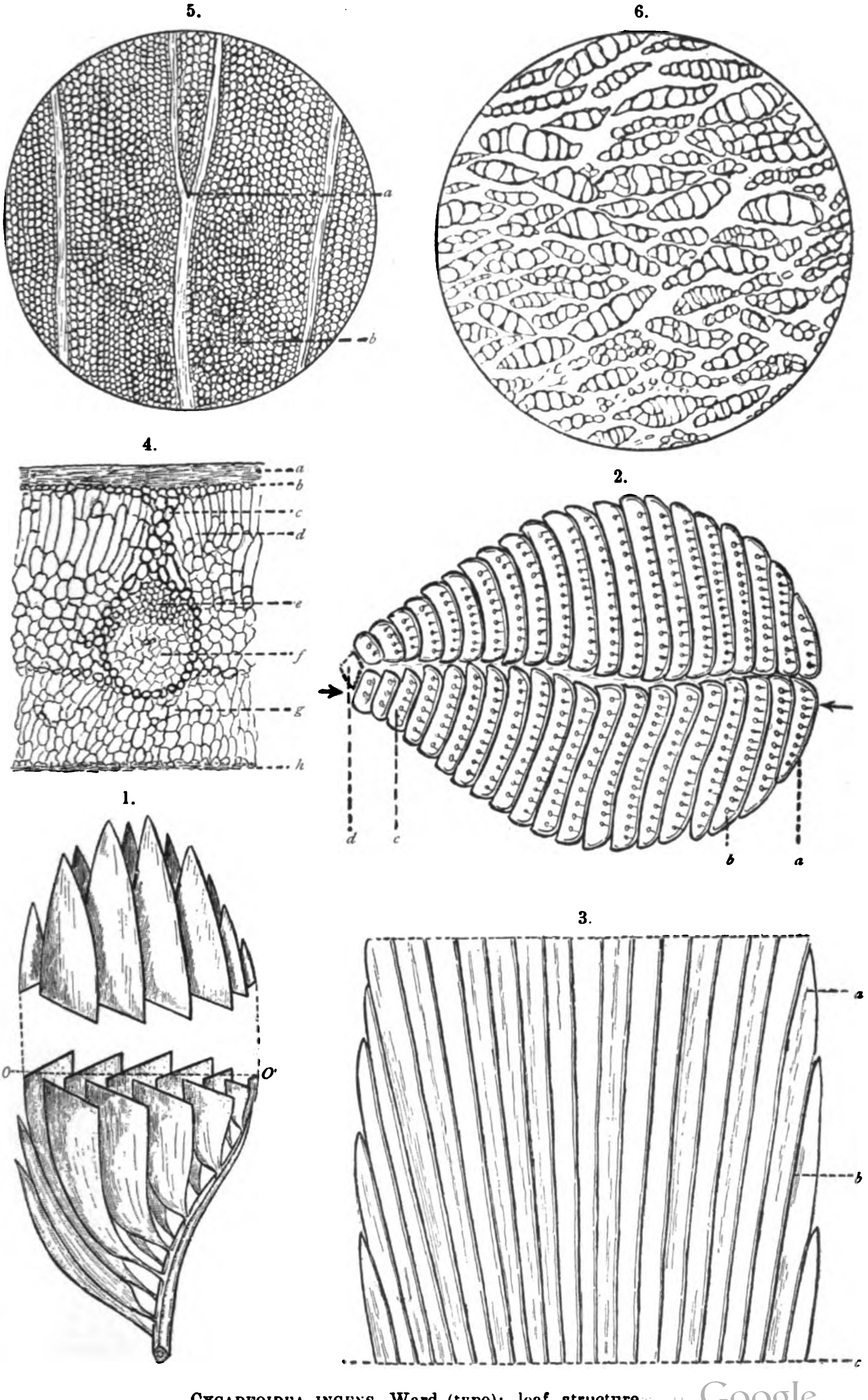
FIGURE 2.—*Cycadeoidea ingens*, Ward (type); transverse section through upper portion of young leaf. × 4. For relative position, see figure 1.
a, upper side of an inner pinnule cut near the summit; *b*, fibro-vascular bundle; *c*, pinnule cut near the base; *d*, axis of growth of rachis. The arrows indicate approximately the base line *O*, *O'*, figure 3.

FIGURE 3.—The same specimen; longitudinal section through summit of young leaf. × 4. For relative position, see figure 1.
a, summit of a pinnule near apex of leaf; *b*, upper side of pinnule; *c*, base line of section indicated in figure 1, *O*, *O'*.

FIGURE 4.—The same specimen; transverse section through a single pinnule, showing a fibro-vascular bundle. × 60.
a, upper side of leaf; *b*, hypodermis; *c*, sclerenchyma connection of hypodermis with fibro-vascular bundle; *d*, palisade parenchyma; *e*, xylem; *f*, phloem; *g*, spongy parenchyma; *h*, epidermis of under side of leaf.

FIGURE 5.—The same specimen; longitudinal section through a pinnule just beneath the hypodermis cutting the palisade parenchyma. × 35.
a, forking vein; *b*, palisade parenchyma.

FIGURE 6.—The same specimen; transverse section through the ramentum surrounding the young leaves. × 60.



CYCADEOIDEA INGENS, Ward (type); leaf structure

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On Luminous and Chemical Energy.*—The radical distinction which exists between photochemical reactions which are endothermic, in which light energy is converted into chemical energy, and those which are exothermic, in which the light is merely auxiliary, the greater portion of the change being effected by purely chemical agencies, has been recently emphasized by BERTHELOT, who has pointed out that it is only the former class of reactions which are adapted for use in the measurement of luminous energy. He has studied a number of substances when exposed to direct sunlight, to diffused daylight, or when kept in the dark, with reference to the changes thereby produced. The substances were contained in sealed tubes and the effect of different wave-lengths upon them was determined by surrounding them with colored media. Nitric acid when concentrated is decomposed by light at ordinary temperatures, and possibly at still lower temperatures, the reaction being similar to that which takes place in the dark at 100°, and which yields nitrogen peroxide, oxygen and water. The blue rays are most effective in producing the action, which is endothermic and not entirely reversible. The diluted acid is not affected by light, that of density 1·365 undergoing no change after weeks of exposure. The nitrogen peroxide formed tends to absorb those rays which are active in producing it. Iodic acid and oxide, while stable in diffused daylight, are decomposed by direct sunlight, setting free iodine and oxygen; the reaction being analogous to that produced by heat at 300°. It is limited by the absorptive action of the iodine vapor and by the deposition of iodine on the surface of the compound. Hence, while endothermic, this reaction is not suitable for the measurement of light energy. The action in the case of hydrogen iodide is on the line limiting endothermic and exothermic reactions, though the author's view is that a small amount of heat (0·4 calory) is evolved; though when solid iodine is set free, it is decidedly exothermic, 6·4 calories being evolved. The blue and violet rays are most effective, and the decomposition is most rapid in direct sunlight, there being an intermediate production of hydrogen periodide (HI_3?). Hydrogen bromide is not affected by the action of light even at 100°. Nor was any action observed with CO_2 either alone or mixed with hydrogen, with CO alone or mixed with hydrogen or oxygen, with SO_2 or HNO_3 when mixed with hydrogen. Red mercuric oxide is more rapidly decomposed than the yellow variety. Mercurous oxide when exposed to light yields traces of metallic mercury. No action was noticed with lead peroxide, silver oxide, or with mercuric chloride, bromide or iodide. Hence the author considers that the measurement of luminous energy by transformation into chemical

energy is to be effected by means of endothermic reactions whi
are irreversible at ordinary temperatures.—*C. R.*, cxxvii, 143-16
July, 1898. G. F. B.

2. *On the Homogeneity of Helium.*—By diffusion through
pipe stem, RAMSAY and TRAVERS separated a volume of heliu
first into six fractions. The first fraction was then pump
into the diffusion vessel, where one-half of it was diffused a
transferred to vessel (1). Fraction No. 2 was then added a
one-third of the mixture was diffused and transferred to vess
(1). Fraction No. 3 was then added and one-half of the who
diffused and transferred to vessel (2). Fraction No. 4 was th
added and one-half diffused and transferred to vessel (3); and
on. Four complete fractionations of this sort in the case of a
gave at the extreme fractions 17·37 and 22·03 per cent of oxyg
respectively. When nitrogen was thus used, prepared fro
ammonium chloride and sodium nitrite, thirty fractionations pr
duced no variation in density. In the case of helium, repeat
fractionations of the gas from samarskite and cleveite gave a g
of density 1·98 and of refractivity 0·1238 as the lightest fracti
and a very little pure argon as the heaviest one. Since furth
diffusion did not alter the density of the lighter fraction, th
authors regard it as pure helium. "It appears therefore th
helium contains no unknown gas nor is it possible to separate
by diffusion into any two kinds of gas; all that can be said
that most minerals which evolve helium also evolve argon
small quantity." The authors had hoped to find a gas wi
density 10 and atomic mass 20; since this would form with He
4 and A = 40 a triad like that of F, Cl and Mn, 19 : 35·5 : 5
They still regard the existence of such an element as probable.-
Proc. Roy. Soc., lxii, 316–324, January, 1898. G. F. B.

3. *On the Properties of Ozone.*—By means of liquid air, LADE
BURG has condensed ozonized oxygen to a liquid. Then b
allowing this to evaporate partially, he has obtained a resid
much richer in ozone, since this gas is less volatile than oxyge
So that by repeating the operation, he obtained finally a g
which contained 86·16 per cent of ozone and which had a densi
of 1·3698 as compared with oxygen, this density being determin
from the rate of diffusion. Hence it follows that the density
pure ozone would be 1·456, theory assigning to it 1·5. He fin
that ozone is not as soluble in water as has been supposed, 0·
volume only being absorbed at the ordinary temperature a
pressure, or 0·00002 part by weight. By condensing ozoniz
oxygen, allowing the oxygen to evaporate and then ascertainin
the temperature at which the residual ozone evaporated, a
attempt was made to determine the boiling point of ozone. Th
oxygen volatilized at —186°, leaving 4 or 5^{cc} of an almost bla
opaque liquid, the temperature of which then rose to —125°,
which point the liquid exploded. This temperature therefore ca
be taken only as a lower limit.—*Ber. Berl. Chem. Ges.*, xxx
2508–2515, October, 1898. G. F. B.

4. *On the Preparation of Alkali Nitrites.*—It has been pointed out by **Divers** that the common impression that in preparing alkali nitrites by passing nitrous fumes into alkali solutions, a method proposed by Fritsche in 1840, there is also produced much nitrate, is erroneous. The nitrous gases are made from nitric acid and starch or arsenous oxide, and are passed into the concentrated solution of the hydrate or carbonate until neutralization is effected; the vessel being loosely stoppered. The strength of the acid and the temperature are so regulated that the nitrogen monoxide is in excess of the dioxide. If the solution is acid, it must be boiled until neutral before exposing it to the air. Then the solution may be freely evaporated to crystallization. Both potassium and sodium nitrites are slightly yellow in color and are slightly alkaline. Sodium nitrite fuses at 271° and at 15° five parts of it requires six parts of water to dissolve it. It is moderately deliquescent, and its crystals are anhydrous. Potassium nitrite is very deliquescent, is soluble in about one-third its weight of water, and its crystals are reputed to contain half a molecule of water.—*J. Chem. Soc.*, lxxv, 85, January, 1899.

G. F. B.

5. *On the Composition of American Petroleum.*—By means of a combined dephlegmator and regulated temperature still-head, **Young** has succeeded in preparing from American petroleum ether a number of nearly pure hydrocarbons. In some cases the fractional distillation was preceded by treatment with mixed nitric and sulphuric acids, in order to remove the benzene. Evidence of the presence of the following has been thus obtained: Isopentane B. P. 27·95°, normal pentane B. P. 36·3°, pentamethylene B. P. about 59°, isohexane B. P. about 61°, normal hexane B. P. 68·95°, methylpentamethylene B. P. about 72°, benzene B. P. 80·02°, hexamethylene B. P. 80·8°, isoheptane B. P. 90·3°, dimethylpentamethylene (?) B. P. about 94°, normal heptane B. P. 98·4°, methylhexamethylene B. P. about 102° and toluene B. P. 110·8°. These results show that the same classes of hydrocarbons, paraffins, polymethylene compounds or naphthenes and aromatic hydrocarbons are present in petroleum from all three sources, but that Russian petroleum contains a relatively larger amount of naphthenes and in all probability, of aromatic hydrocarbons than Galician, and Galician a larger amount of the same hydrocarbons than American petroleum.—*J. Chem. Soc.*, lxxiii, 905–920, December, 1898. G. F. B.

6. *Electrical waves along wires.*—A. **Sommerfeld** has examined by means of elaborate mathematical analysis this subject, and has calculated the rate of damping and the decrease of velocity for the case of wires of different diameters. In the case of a copper wire 4^{mm} thick with a period of 10^9 per second, the electric wave velocity was 8 kilometers below the velocity of light. With a platinum wire of $\frac{4}{1000}^{mm}$ diameter, period $3 \cdot 10^6$ per second, the velocity falls to $\frac{3}{4}$ of the velocity of light. The ordinary experimental method, in which two parallel wires are used,

offers great mathematical difficulties. The author is apparently unacquainted with the direct experimental determination of the velocity of electric waves by Professor Trowbridge and Professor Duane, which avoids the mathematical difficulties, and by which a velocity closely agreeing with that of light was obtained.—*Wied. Ann.*, No. 2, 1899, pp. 233–290. J. T.

7. *Polarization and hysteresis in dielectrics.*—W. Schaufelberger employs ellipsoids of paraffine and hard rubber, and studies the damping of their oscillations in the electric field of a Kohlrausch condenser. The mathematical consideration of the motion of the dielectric contains hypotheses drawn from analogous phenomena of polarization and hysteresis in the case of iron. It was found that the loss of energy due to hysteresis in paraffine is 2·119 per cent and in hard rubber 63·49 per cent. The latter number is regarded as an approximation.—*Wied. Ann.*, No. 2, 1899, pp. 307–324. J. T.

8. *A new method of showing electric waves.*—A simple resonator devised by Rhigi consisted in a sheet of tinfoil applied to glass, the foil being divided by a fine line. Albert Neugschwender has discovered that if a galvanometer and a battery are placed in circuit with a silver-coated surface divided by a fine line, that the galvanometer will show a deflection due to a Hertzian wave if one breathes on the metallic surface or places a wet sponge near it. The vapor converts the divided surface into a species of coherer.—*Wied. Ann.*, No. 2, 1899, pp. 430–432. J. T.

9. *Separation of long waves of heat by means of quartz prisms.*—The very important work of H. Rubens and E. Aschkinass on this subject has shown that it is possible by means of quartz and sylvine to isolate waves of heat of great wave-length, since these waves are not absorbed by these substances. The above authors have now entered into a discussion of the further extension of their method. They find that intensity of energy between wave lengths 50μ and 60μ is greater than the whole energy beyond $\lambda = 60\mu$. Since the energy between 50 and 60μ is only $\frac{1}{100,000}$ of the whole amount of energy emitted by the sources employed by them (Auer burner), it does not appear possible to further extend their method.—*Wied. Ann.*, No. 2, 1899, pp. 459–466. J. T.

10. *Theory of conduction of electricity through gases by charged ions.*—Professor J. J. Thomson has reduced his observations upon this subject to a mathematical form, and has obtained equations which embody his experimental results. He explains many of the phenomena observed in Geissler tubes, and believes that the most striking features of the discharge through vacuum tubes are due to the difference in velocity between the positive and negative ions. He points out that a study of the distribution of intensity in Geissler tubes supports the theory of ionization.—*Phil. Mag.*, March, 1899, pp. 253–268. J. T.

11. *The Hall phenomenon and the theory of Lorentz.*—Poincaré

has applied Lorentz's theory of electrical ions to the Hall phenomenon and has obtained an equation which represents the electromotive force obtained by Hall. He concludes that it would be desirable to examine whether all metals exhibit the Hall effect when they carry currents of very high electromotive force and whether a change of sign occurs.—*Comptes Rendus*, No. 6, Feb., 1899, pp. 339–341. J. T.

12. *On the Relation of the Surface Tension and Specific Gravity of certain Aqueous Solutions to their State of Ionization.*—Prof. MacGregor has shown that it is possible to calculate the various properties of solutions of potassium and sodium chloride in terms of the state of ionization of the electrolytes contained. The relation derived, in its simplest form, is $S=S_w+k(1-a)n+lan$. where S is the numerical value of any property of a solution (density, surface tension, etc.), S_w that of the same property of water under the same physical conditions, n the number of equivalent gram-molecules per unit volume, a the ionization coefficient of the electrolyte in the solution, and l and k constants, called ionization constants, for any given property of any given electrolyte. Mr. E. H. **Archbald** has carried out a similar series of observations and calculations in the case of simple solutions of sodium, potassium and copper sulphates, salts of more complex molecular structure than those previously examined. He concludes that the expression given represents observed values of the surface tension and specific gravity of the solutions examined through a range of concentration extending from 0·05 to about 0·4 or 0·5 equivalent gram-molecules per liter. Further, that it is possible by aid of the dissociation theory of electrolysis to predict the surface tension and specific gravity of mixtures of potassium and sodium sulphate solutions and the specific gravity of mixtures of solutions of potassium and copper sulphates throughout nearly the same range, within the limits of the error of observation. And similarly, that it is possible to predict the specific gravity of mixtures of solutions of potassium sulphate and sodium chloride.

13. *On the Cause of the Absence of Coloration in certain Limpid Natural Waters.*—Professor W. **Spring** has an interesting article upon this subject in a recent number of the *Bibliothèque Universelle* (Jan. 15, 1899). Recognizing the accepted fact that pure water is distinctly *blue*, he remarks that the green color often observed is easily explained as due to the presence of more or less muddiness, which acts with the natural blue color to give a sensation of green. The absence of color, however, is a different problem, as early noted by Berzelius. The results of some experiments have led the author to the hypothesis that the suspension of minute, perhaps invisible, particles of anhydrous ferric oxide, or hematite, would have, through their red color, the effect of neutralizing the blue and leaving the water completely colorless. He notes the fact that microscopic grains of hematite are almost always found distributed in the soil, and that terrestrial waters have rarely the blue color which the pure liquid

should show. On the contrary, the water derived immediate from snow at high altitudes, or from glaciers, contains no hem tite and is commonly intensely blue. The action of hydrat ferric oxide is different, since its color is yellow, and when prese in very small amounts in the water, there is, so to speak, a strugg between it and the organic matter; if not overcome, the effect to make the water appear green to the eye.

14. *A Text-Book of General Physics for the use of Colleg and Scientific Schools;* by CHARLES S. HASTINGS and FREDERI E. BEACH; pp. viii, 768. Boston, 1899 (Ginn & Company). The appearance of a new high grade text-book of physics is event of much importance to all teachers and students in th department. The authors are to be congratulated upon th admirable manner in which they have treated the entire subje particularly for their success in adequately presenting so vast range of topics within the limits of a single moderate-siz volume. The work is characterized by the very careful a thorough treatment of the fundamental conceptions of the s ence; by the well-balanced relation between the different par no one portion of the subject being sacrificed to another ; by t clear and precise mathematical development of each successi principle. At many points, moreover, though dealing with topi often treated of, there is much that is fresh and suggestive; th is particularly true of the chapters on Light.

The conciseness of expression and the mathematical, thoug elementary, method of presentation adopted have the advanta of brevity and accuracy, but they may leave much for t teacher to do if his pupils are approaching the subject for t first time. The student, however, who is properly prepared, w find no serious difficulty, and his subsequent work in speci advanced fields will be much facilitated by the thorough groun ing in principles and methods which he has here obtained.

Too much praise cannot be given to the publishers for t admirable form in which they have placed the work before t public. The page is clear and open, with no confused crowdi of mathematical expressions, while the excellence of topograph illustrations and paper leaves nothing to be desired.

II. GEOLOGY AND MINERALOGY.

1. *New facts regarding Devonian Fishes. Dentition Devonian Ptyctodontidea;* by C. R. EASTMAN; Am. Nat., vo xxxii, pp. 473–488 and 545–560. July and August, 1898. *Som new points in Dinichthyid Osteology;* by C. R. EASTMAN; Am Nat., vol. xxxii, pp. 747–768. October, 1898.—The first of thes papers is the result of study of the rich material from the Stat Quarry fish-beds discovered by Prof. Calvin in the Devonian o Johnson County, Iowa (see Ann. Rept. Iowa Geol. Survey, vo vii, 1897); private collections made by Mr. E. E. Teller and C. Monroe from the Hamilton limestone quarries of Milwauke

Wis.; and the Schultze collection in the Museum of Comparative Zoology containing European fish remains. The species described belong to the genera *Ptyctodus* Pander, *Rhynchodus* Newberry, *Palæomylus* Woodward, and ichthyodorulites are described under the new generic names *Phlyctænacanthus* and *Belemnacanthus.*

The stratigraphic relations of the fish remains and their association with invertebrate fossils lead the author to agree with the general conclusions of Stuart Weller regarding the relation of the Milwaukee beds to the New York and Iowa faunas.

"The Chimæroids give it (the hydraulic limestone of Milwaukee) a stamp of antiquity, suggesting that a westward migration took place during the early part of the Devonian as far as Wisconsin, but not crossing the Mississippi Valley until the Middle Devonian. The Milwaukee beds show the first traces of the encroachment from the East, the Rock Island locality a somewhat later, and the state quarry limestone the last of all, with its horde of Upper Devonian lung-fishes."

The second paper gives a critical comparative study of the cranial osteology of the Dinichthyids, with a particular description of an early type, *D. pustulosus* Eastman, based upon specimens from the Milwaukee and Iowa localities. The author considers this species to be the most primitive member of the genus known. His studies lead him to regard *Coccosteus* and *Titanichthys* as the extreme limits of the family Coccosteidæ, with *Dinichthys* as an intermediate and connecting link. Speaking of the *Dinichthyids* the author says: "But when their characters shall have been fully investigated, the wide range of variation manifested by them will be found reducible to order, and the whole promises to constitute one of the most interesting evolutionary series known among fossil fishes" (p. 747).

H. S. W.

2. *Geological Sketch of San Clemente Island;* by W. S. T. Smith. Extr., 18th Ann. Rept., U. S. Geol. Survey, 1896–97, Part II, pp. 459–496, plates lxxxiv–xcvi, figs. 82–85. 1898.—San Clemente is the southernmost island of the "channel islands" off the southern coast of California. The island has been described as a "tilted orographic block" by Lawson. The rocks are chiefly volcanic. The oldest sedimentaries are of Miocene age. The author recognizing this as a typical fault block, and isolated from other land masses, the topography of which is still in its infancy, has presented a theory as to the development of its drainage. He also describes the structural and petrographic features of the volcanics, and a general description of the sedimentaries, moraines and later deposits.

H. S. W.

3. *Geology of the Edwards plateau and Rio Grande plain, etc.;* by Robert T. Hill and T. Wayland Vaughan. Extr., 18th Ann. Rept., U. S. Geol. Survey, 1896–7, Part II; pp. 193–321, plates xxi–lxiv, figs. 53–76. 1898.—The geological features of the region from Austin, Texas, westerly and southwesterly through San Antonio to the Rio Grande, are described and beauti-

fully illustrated in this report. Although it does not attempt to be an exhaustive paper on the statistics and engineering problems incident to developing the water supplies, the geology is presented in its relations to the occurrence of underground waters, their sources and relations to the beds carrying them. The paper not only presents an admirable exposition of geological structure, but must prove of great value in guiding the inhabitants of the region in supplying themselves with large supplies of fresh waters.

H. S. W.

4. *South Dakota Geological Survey, Bulletin No. 2;* by James E. Todd, State Geologist; pp. 1–139, plates i–xv, figs. 1–2. 1898.—This second bulletin contains the 1st and 2d biennial reports with accompanying papers for the years 1893 to 1896. The papers of chief importance are accounts of the surveys of a Section along Rapid Creek from city westward; A reconnoisance into northwestern South Dakota; The geology along the Burlington and Missouri Railway; and Additional notes on the limits of the main Artesian Basin, i. e., additional to those reported by the U. S. Geological Survey in the 17th and 18th Annual Reports. Numerous detailed sections of the rocks and reproduced photographs of the structure are given. H. S. W.

5. *Crater Lake, Oregon;* by J. S. Diller. Extr. Smithsonian Report for 1897, pp. 369–379, plates i–xvi. 1898.—This paper, though a reprint of one which first appeared in the National Geographic Magazine (1897),* will bear repeating, holding as it does beautiful illustrations of a region of which the author says:

"Aside from its attractive scenic features, Crater Lake affords one of the most interesting and instructive fields for the study of volcanic geology to be found anywhere in the world. Considered in all its aspects, it ranks with the Grand Cañon of the Colorado, the Yosemite Valley, and the Falls of Niagara, and it is interesting to note that a bill has been introduced in Congress to make it a national park for the pleasure and instruction of the people."

H. S. W.

6. *International Geological Congress.*—The eighth session of the International Geological Congress will be held in Paris in 1900 between the 16th and the 28th of August. The Committee of Organization has announced twenty-two excursions, three of which are general; I, about the Paris Basin; II, Boulonnais and Normandie; III, the volcanic regions of central France. The other nineteen are special local excursions for the study of particular problems. A *livret-guide* will be prepared and ready for distribution the early part of 1900. M. Albert Gaudry, Paris, is the President, and M. Charles Barrois, Lille, is General Secretary of the Committee of Organization. H. S. W.

7. *International Geographical Congress.*—The Geographical Society of Berlin (Gesellschaft für Erdkunde zu Berlin, F. Baron von Richthofen, Prest., George Kollen, General Secy.) invites the friends and promoters of geography in all countries, and especially

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* See also this Journal for March, 1897.

the members of all geographical societies and cognate scientific bodies or institutes, to assemble at the German capital, Berlin, for the meeting of the seventh International Geographical Congress, to be held from Sept. 28th to Oct. 4th, 1899. Membership tickets may be obtained by gentlemen or ladies by payment of 20 marks to the Treasurer, H. Bütow, 90 Zimmerstrasse, Berlin S. W. All wishing to read papers before the Congress are requested to give notification thereof before April 1st, 1899, and to send the manuscript ready for print not later than June 1st, 1899.

H. S. W.

8. *Funafuti.*—The January number of *Natural Science* contains an interesting and popular discussion of the life and geological features of Funafuti as a typical coral atoll, by W. J. Sollas. Special interest attaches to this island in consequence of the work which has been done here in boring into the coral rock. The party sent out from England, which was directed by Professor Sollas, unfortunately did not succeed in carrying the boring to any considerable depth. The work, however, was continued in 1897 under the direction of Professor David of the University of Sydney, and this time was entirely successful, the reef being penetrated to a depth of 697 feet. Later, a third party was sent from Sydney, which has carried the boring on to a depth of about 1000 feet. The core obtained by the David party was sent to England and is now in the hands of Professor Judd for investigation, the results of which will be awaited with much interest. The general statement is made, however, that the material brought up from the boring, of which the reef is composed, presents much the same character throughout, and so far is regarded as supporting Darwin's theory. There are no layers of chalky ooze, such as Murray's hypothesis might have made probable, and no trace of volcanic material was found. The later boring beyond 700 feet has passed through a hard limestone, containing many well-preserved corals. The last mentioned expedition has also carried on a boring into the bed of the lagoon to a depth of 144 feet. After passing through 101 feet of water, the first 80 feet below were found to consist of the calcareous alga Halimeda, mixed with shells; the remaining 64 feet, of the same material mixed with coral gravel.

9. *Petrographical and Geological Investigations of certain Transvaal Norites, Gabbros, and Pyroxenites;* by J. A. Leo Henderson (8° pamph., 56 pp., 5 pl., Dulau & Co., Pub., London, 1898).—Although this appears as a separate work, one is led to infer that it is a thesis presented for the doctor's degree at Leipzig. The material upon which the investigations have been carried is from the Stelzner collection at Freiberg and was gathered by the explorers Mohr and Goerz. As may be inferred, therefore, it is a minute and painstaking petrographical and chemical investigation of a series of hand specimens determined as diallage norite, hypersthene norite, hypersthene diallage gabbro, quartz norite, quartz diallage norite and enstatite pyroxenite.

In addition some gneisses and other rocks are described. Among them is a syenite and syenite porphyry which are shown to have anorthoclase (soda microcline) as the feldspar, and the author believes this to be a sufficient ground for the erection of a new rock group and proposes the names of *hatherlite* and *pilandite* for them respectively. Probably the majority of petrographers will hardly agree to this, since as commonly understood the syenite family is one composed essentially of alkaline feldspars in general and not one particular variety of them. As a matter of fact, the pure potash feldspar is of very rare occurrence as a rock-ingredient and the great majority of the so-called orthoclases contain the albite molecule to a greater or less extent. Moreover since the analyses of the feldspars of the rocks mentioned show that they contain a very considerable quantity of lime, it appears questionable whether they should not be classed as abnormal oligoclases rather than anorthoclase (soda microcline); they are clearly not typical examples of the latter.

Very full and painstaking investigations have been made in this work of the augitic constituents of the rocks mentioned which have been separated and analyzed, but it seems rather curious from modern standpoints that with so much chemical investigation of the constituents no mass analyses of the rocks except in one case have been made. This is a rock consisting of enstatite crystals including 4·5 per cent of anorthite plates. The analysis gave:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	H_2O	Sp. G. = 3·3
55·23	0·44	2·08	3·94	6·25	29·29	1·68	1·12	= 100·03

It is an enstatite pyroxenite from the Central Marico District.

L. V. P.

10. *On the Occurrence of Corundum.*—Two recent papers on the occurrence of corundum in widely separated parts of the world deserve to be mentioned. One of these, by T. H. Holland,* discusses in detail the various corundum localities, including the gem varieties, ruby and sapphire, in India and the adjacent countries. The second paper, by W. G. Miller,† describes the corundum and associated minerals of Eastern Ontario.

The most interesting point brought out in both papers is the fact that corundum occurs so often associated with igneous rocks; this fact has also been recently established in other regions. Mr. Holland accepts the fact that in certain cases it may have a secondary origin, as shown by Professor Judd for the ruby, but for the most part he regards it as an original constituent, though often due to the local excess of alumina. The Indian localities are divided into those in which the corundum occurs with basic rocks and these in which its associates are siliceous, that is, *acid*. In the former class pyroxene is the predominating constituent, together with some member of the spinel group. These occurrences are divided into three groups. In the first, the *ferruginous* group, the pyroxene is a highly ferriferous enstatite and the spinel either hercynite, or hercynite with magnetite; in this group ilmenite may largely replace the corundum. In the second, the *ferro-magnesian* group, ferrous oxide is largely replaced by magnesia, a less ferriferous enstatite and pleonaste, also sometimes chrysolite, being the type minerals. In the third, or *magnesian* group, iron compounds occur in very small quantity, the associated minerals being magnesian forms of chrysolite, also (secondary) talc, dolomite, magnesite.

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* A Manual of the Geology of India: Economic Geology by the late Professor V. Ball. Second edition revised in parts. Part I, Corundum, by T. H. Holland; pp. 79, Calcutta, 1898.

† Report of the Bureau of Mines, vol. vii, third part, pp. 207–265, Toronto, 1898.

In the second class, the corundum is associated with *acid* rocks. This is well illustrated by the sapphire of Kashmir, which occurs in granite; here the granite (pegmatite) forms veins in gneiss and carries with the sapphire, tourmaline, euclase, cyanite, etc.; green tourmaline, spodumene, cookeite and prehnite are also found. The gneiss is coarse and schistose, with white feldspar, black mica and also garnets.

The corundum of Ontario, as described by Mr. Miller, belongs chiefly to dikes of syenite and quartz pegmatite intersecting the Laurentian gneiss. It is found more abundantly in ordinary syenite than in nepheline syenite, but in the latter the crystals are better formed. It is also found in eastern Ontario in crystalline limestone, as in Burma, where it is regarded as of secondary origin. Mr. Miller's paper is accompanied by numerous interesting plates illustrating the actual occurrence of the mineral. Other mineralogical points are also brought out, as the occurrence of nickel-bearing magnetite, also of a mineral of the columbite type (G.=5·40), in Renfrew County.

11. *Minerals in Rock Sections:* The practical methods of identifying minerals in rock sections with the microscope. Especially arranged for students in technical and scientific schools. By LEA MCILVAINE LUQUER; pp. 117. New York, 1898 (D. Van Nostrand Company).—This subject has been already treated of by a number of authors, but there still remains place for the present volume. It gives in the opening chapters a concise summary of the optical principles, methods and instruments, and following a statement of the characters of minerals arranged with system and clearness. A chapter is also added on the methods of making sections and one on chemical tests. An optical scheme is added in the appendix.

12. *New Mineral Names.*—LAGORIOLITE. In connection with his important work in mineral synthesis and the crystallization of minerals from a molten magma, Morozewicz has obtained isometric crystals or crystalline grains of a mineral having the composition $(Na_2Ca)_3Al_2(SiO_4)_3$, in which $Na_2 : Ca = 3 : 2$. This corresponds to a sodium-grossularite, a type of garnet not yet noted in nature but which has peculiar interest as connecting the garnets with the minerals of the Sodalite Group. This compound is named after Prof. A. Lagorio.—*Min. petr. Mitth.*, xviii, 147, 1898.

Thalenite. A new yttrium silicate, having the composition $H_2Y_4Si_4O_{15}$. It occurs in tabular monoclinic crystals of a flesh-red color. Hardness = 6·5; specific gravity = 4·229. Found in Österby in Dalecarlia, Sweden, and named by Benedicks after Prof. R. Thalén.—*G. För. Förh.*, xx, 308, 1898.

Ktypeite. A name given by Lacroix to the calcium carbonate in the form of pisolites from Carlsbad and Hammam-Meskoutine in Algeria, which has formerly been referred to aragonite. The specific gravity varies from 2·58 to 2·70, or less than that of calcite. Optically the birefringence is 0·020. In parallel polarized light a distorted black cross is noted, while portions give a positive black cross in converging light. Heated to low redness, the pisolites decrepitate and are finally transformed into calcite; the name given refers to this fact.—*Comptes Rendus*, cxxvi, 602, 1898.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Benjamin Apthorp Gould Fund.*—A circular has recently been issued by the Directors of the Gould Fund, Professors Lewis Boss, Seth C. Chandler and Asaph Hall, stating that a sufficient available income has now accrued to warrant beginning its distribution, and that they are prepared to receive and consider applications for appropriations. It will be remembered that the fund was established in November, 1897, when the sum of twenty thousand dollars was given to the National Academy of Sciences, as trustee, in memory of the father of the donor, Miss Alice Bache Gould, the income to be used to assist the prosecution of researches in astronomy.

In order to guide those desiring to secure appropriations from the fund, the directors make the following statement:

The objects of the institution are, first, to advance the science of Astronomy; secondly, to honor the memory of Dr. Gould by ensuring that his power to accomplish scientific work shall not end with his death. In recognition of the fact that during Dr. Gould's lifetime his patriotic feeling and ambition to promote the progress of his chosen science were closely associated, it is preferred that the fund should be used primarily for the benefit of investigators in his own country or of his own nationality. But it is further recognized both by the donor and the directors that sometimes the best possible service to American science is the maintenance of close communion between the scientific men of Europe and of America, and that, therefore, even while acting in the spirit of the above restriction, it may occasionally be best to apply the money to the aid of a foreign investigator working abroad. The wish was also expressed by the donor that in all cases work in the astronomy of precision should be given the preference over any work in astrophysics, both because of Dr. Gould's especial predilection and because of the present existence of generous endowments for astrophysics.

Finally, the Benjamin Apthorp Gould Fund is intended for the advancement and not for the diffusion of scientific knowledge, and is to be used to defray the actual expenses of investigation, rather than for the personal support of the investigator during the time of his researches, without absolutely excluding the latter use under the most exceptional circumstances.

Application for appropriations from the income of this fund may be made informally by letter to any of the directors, stating the amount desired, the nature of the proposed investigation, and the manner in which the appropriation is to be expended. If favorably considered, a blank for formal application will be forwarded for signature, with the rules adopted by the directors for the administration of the fund, and to which the applicant will be expected to subscribe.

2. *Annual Report of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1896. Report of the U. S. National Museum;* pp. xxiv, 1107. Washington, 1898.—The Report of the United States National Museum for the year ending June 30th, 1896, has recently been issued. It includes the report of the Assistant Secretary, the late Dr. G. Brown Goode, which gives, in addition to matters of current interest, an outline of the history of the Museum, showing how it has grown to its present dimensions. A series of Appendices relating to Museum matters follow.

Part II of the volume, covering nearly 750 pages, includes a paper entitled: An account of the United States National Museum by Frederick W. True (reprinted); also a series of ethnographical papers elaborately illustrated with many text figures and full page plates. The first of these, by Thomas Wilson, discusses the origin of art as manifested in the works of pre-historic man; those not acquainted with the subject will be surprised to see what a variety of objects is here described and illustrated and how great interest attaches to them. The other articles are on Chess and Playing Cards by Stewart Culin; Biblical Antiquities by Cyrus Adler and I. M. Casanowicz; The Lamps of the Eskimo by Walter Hough.

3. *The Second Washington Catalogue of Stars: together with the Annual Results upon which it is based.* The whole derived from Observations made at the U. S. Naval Observatory with an 8·5 inch transit circle, during the years 1866 to 1891, and reduced to the epoch of 1875·0. Prepared under the direction of JOHN R. EASTMAN, Professor of Mathematics, U. S. N., Washington Observations for 1892, Appendix I, pp. lxiii, 287, Washington, 1898.—This large volume of star observations, as stated in the preface by the Director of the Observatory, Professor Harkness, has absorbed the labors of about two-thirds of the Observatory staff for more than thirty years, during the greater part of which time Professor Eastman was in immediate charge. His personal work included 17,334 observations of stars, out of nearly 73,000; and nearly 40,000 were made under his immediate direction. Professor Harkness adds that the credit and responsibility for the methods of discuss-

ing the observations, for the values of the systematic corrections applied in the formation of the final places, and for the arrangement of the volume rest with Professor Eastman.

4. *Zoological Results based on material from New Britain, New Guinea, Loyalty Island and elsewhere, collected during the years 1895–1897;* by ARTHUR WILLEY, Cambridge, England, Part II, pp. 121–206, plates xii to xxiii.—The first part of this important series of memoirs was noticed in the January number of this Journal (p. 79). The present part contains the following seven papers: 7, Report on the specimens of the genus *Millepora*, by S. J. Hickson, pl. xii–xvi; 8, On the Echinoderms (other than the Holothurians) by F. Jeffrey Bell, pl. xvii; 9, Holothurians, by F. P. Bedford, pl. xviii; 10, On the Sipunculoidea, by A. E. Shipley, pl. xviii; 11, On the Solitary Corals, and 12, On the postembryonic development of *Cycloseris*, by J. Stanley Gardiner, pl. xix, xx; 13, On a collection of Earthworms, by F. E. Beddard, pl. xxi; 14, On Gorgonacea, by Isa L. Hiles, pl. xxii, xxiii. Part III is stated to be now in press.

5. *A Select Bibliography of Chemistry, 1492–1897;* by HENRY CARRINGTON BOLTON. First Supplement; pp. ix, 489. Washington, 1899. (Smithsonian Miscellaneous Contributions, 1170.)—Workers in science owe much to the careful and painstaking labors of those who prepare the bibliographies in the different departments. One of the most complete of these is the Bibliography of Chemistry, 1492–1892, by Professor Bolton, which was issued in 1893. A First Supplement to this work has now been issued, bringing the literature of the subject down to the close of 1897. This is a closely printed volume of nearly five hundred pages, which fact alone gives evidence of the large amount of material brought together. The total number of titles is 5554 in twenty-five different languages; these titles are classified under the following seven heads: Bibliography; Dictionaries and Tables; History of Chemistry; Biography; Chemistry, Pure and Applied; Periodicals.

6. *Biological Laboratory.*—The Biological Laboratory of the Brooklyn Institute of Arts and Sciences will be located for its tenth season at Cold Spring Harbor, Long Island, during the months of July and August, 1899. The director of the laboratory is Charles B. Davenport, Ph.D. of Harvard University. A circular giving the names of instructors, courses of study offered, equipment and other details has recently been issued, and copies may be obtained from Prof. F. W. Hooper, 502 Fulton st., Brooklyn.

THE

AMERICAN JOURNAL OF SCIENCE

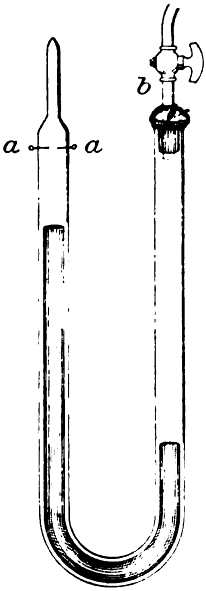
[FOURTH SERIES.]

Art. XXXIV.—*On some Experiments with Endothermic Gases;* by W. G. Mixter.

[Contributions from the Sheffield Laboratory of Yale University.]

These experiments were made in U-tubes of 30 to 50^{cm} in length and for high pressures the form shown in fig. 1 was employed. The part above the electrodes *a a* was narrowed for convenience in opening the tube and measuring small residual quantities of gases. The other end was connected by means of a small copper tube with a hydraulic pump. At *b*

1.



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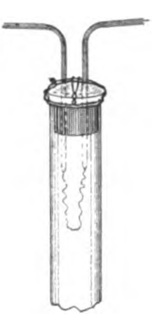
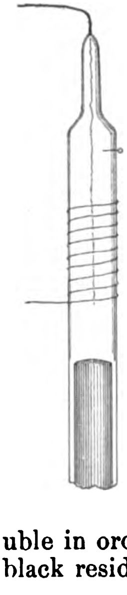


was a thick wrapping of cotton wicking to protect the rubber stopper from the wire used to hold it in place. Such a connection answered for a pressure of 20 atmospheres by the pump and withstood explosions that burst the other limb of the U-tube. For filling the apparatus a little mercury was poured in to form a trap at the bend and the air was displaced by passing in a liter or more of gas through a small rubber tube reaching to the closed end; then more mercury was added, the stopper adjusted, the apparatus placed in a tall glass jar to prevent danger from flying glass and to catch the mercury in case the tube broke. The desired pressure was obtained by forcing in water with a pump. For pressures of three atmospheres or less a reservoir of mercury connected by means of a rubber tube was convenient, the heighth of the mercury in the reservoir above its surface in the U-tube being the measure of the pressure. For heating gases by a glowing wire the end with the electrodes in fig. 1 was modified as indicated in fig. 2. To the heavy copper wires passing through the rubber stopper was soldered a platinum wire which was made to glow or even melt by a battery current.

Acetylene.

Berthellot and Vieille* have investigated the explosion of acetylene, and hence it is only necessary to state that my results, obtained before their paper was published, accord with theirs and that they are briefly given in order to show that the other endothermic gases tested do not explode in the same apparatus and under the same conditions. At a pressure of two atmospheres when an electric spark was passed or a platinum wire was made to glow in the gas it sometimes did not explode, while at a pressure of three or more atmospheres explosions always occurred. If, however, the sparks are small acetylene does not explode even at high pressures. A number of tests were made in a tube shown in part in fig. 3, containing acetylene under various pressures up to 20 atmospheres; when the inner and outer wires were connected with an induction coil in action, sparks visible in strong daylight passed between the glass and the inner wire. This form of discharge did not cause explosion. When it continued for some time a reddish deposit appeared. This was insoluble in ordinary solvents, and exploded when heated, leaving a black residue. It was not further investigated. The presence

3.



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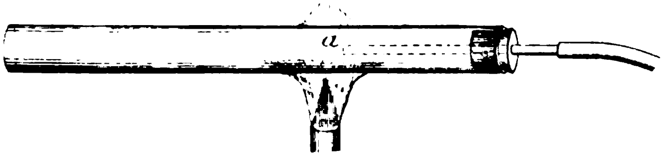
* Compt. Rend., cxxiii, 523.

of an indifferent gas checks the explosion of acetylene, as the following show: A dry mixture of 1 volume of acetylene and 2 volumes of hydrogen at a pressure of 5 atmospheres was not exploded by sparking; carbon separated slowly but there was no cloud of soot. The result was the same with equal volumes of the two gases at 6 atmospheres, while with a mixture of 2 of acetylene and 1 volume of hydrogen at 5 atmospheres, the explosion promptly followed the electric discharge. The spark used was 2^{cm} in air and was passed between electrodes 3^{mm} apart in the gas.

4.



The following experiment illustrates beautifully and simply the endothermic character of acetylene and also shows that a dull red heat is sufficient to decompose it. A slow current of the gas is passed through the tube *a*, fig. 4, into the larger tube, which is heated as shown by a Bunsen burner. When the part of the outer tube about the end of *a* is heated to a faint glow there is a slight puff and then the gas issuing from the end of *a* glows or rather the carbon, separating beyond the end of the little tube, glows. It is a jet of gas filled with a cloud of lampblack glowing with the heat resulting from the dissociation of the acetylene. In order to obtain the result the flow of the gas must be carefully regulated. If too fast, the gas does not attain the temperature of decomposition, and if too slow it does not glow.

Cyanogen.

Experiment 1.—The U-tube, fig. 1, was charged with cyanogen made from dry mercuric cyanide. The gas was nearly free from air or other permanent gases, as it was found that 100^{cc} left only a small volume of gas when liquefied by pressure. When induction sparks were passed through the vapor of cyanogen at a pressure of about five atmospheres, at which a portion of the compound was liquid, carbon separated at once and connected the electrodes. There was no explosion and no decomposition except in the path of the spark. A primary current from two large storage cells was next passed, the carbon filament connecting the platinum wires in the tube serving as a conductor. The result was a brilliant violet light and the separation of a little more carbon. The primary current had, however, broken the filament so that on connecting again with a coil in action sparks passed, but soon ceased. The primary current then gave the same result as before. The amount of cyanogen decomposed was small, for of the 100^{cc} taken only 1^{cc} was not absorbed by potassium hydroxide after the experiment.

Experiment 2.—Cyanogen was condensed in the apparatus fig. 2 until a portion liquefied, and the wire was heated white hot by a current from a battery. A slight fog appeared but there was no separation of carbon throughout the gas, and there was no explosion. The result was the same at lower pressures. Finally the platinum wire was melted in the gas at the pressure of liquefaction, but there was no explosion nor any considerable decomposition. A thin coating of carbon had formed on the wire.

Nitrous Oxide.

Experiment 1.—The apparatus, fig. 1, was filled with 72^{cc} of pure dry nitrous oxide, and the gas was condensed to 6^{cc} and sparked. There was no explosion. Faint red fumes appeared. On lowering the pressure after the sparking to that of the atmosphere, the gas showed increased volume but not 50 per cent, as would have been the case had the dissociation been complete.

Experiment 2.—100^{cc} of gas condensed to 5^{cc} and finally to 3^{cc} were sparked for some time. There was no explosion and the volume at the close of the experiment was less than 150^{cc}.

Experiment 3.—70^{cc} of nitrous oxide were condensed to 5^{cc} and sparked. The result was the same as in the preceding experiments.

Experiment 4.—100^{cc} of nitrous oxide condensed to 10^{cc} were sparked. There was no explosion.

In the above tests the platinum electrodes were 4^{mm} apart and the spark used was fairly strong and had a length in air of 3^{cm}.

Nitric Oxide.

Experiment 1.—Dry nitric oxide was sparked at pressures varying from 12 to 20 atmospheres. There was no explosion, but the gas became reddish.

Experiment 2.—100^{cc} of dry nitric oxide were condensed to 10^{cc}. The spark and electrodes were as described under nitrous oxide. The first spark through the gas produced a small flame between the electrodes. The sparking was continued only a few seconds. The gas remaining was nearly all absorbed by a solution of ferrous sulphate, showing that only a small portion of the nitric oxide had been decomposed.

Experiment 3.—50^{cc} of gas were condensed to 6^{cc} and sparked a short time. After treatment with ferrous sulphate only 0·5^{cc} remained.

The deportment of nitrous and nitric oxide in the above tests is much the same as in the well known experiments of sparking these gases at ordinary pressure.

The results of the experiments described in this article will be discussed in the next paper.

ART. XXXV.—*On a Hypothesis to explain the partial non-explosive Combination of Explosive Gases and Gaseous Mixtures;* by W. G. MIXTER.

[Contributions from the Sheffield Laboratory of Yale University.]

MUCH has been done in investigations of the conditions under which gases combine gradually or with explosive violence. The velocity of explosive waves has been determined, and the influences of pressure, and of excess of one gas or dilution with an indifferent one, have been studied. Dixon* states, "The explosive wave is propagated not only by burnt molecules, but also by those of the heated but yet unburnt molecules." But so far as the writer is aware, no hypothesis has been advanced to account for the fact that explosive mixtures will not explode at low pressures, and that weak electric sparks may not cause explosions, where strong sparks do. Victor Meyer, with the aid of his pupils, has made a large number of experiments with explosive mixtures at different temperatures and pressures, but he has offered no explanation of the phenomenon of slow combination in such mixtures. As the union of hydrogen and oxygen has been more thoroughly studied than that of other gases, the deportment of detonating gas, by which is understood equivalent amounts of hydrogen and oxygen, under various conditions, affords the best basis for discussion. The behavior of certain other gases, and the observations of different experimenters, will also be considered.

Dixon† found that detonating gas at a pressure of 70^{mm} does not explode when an electric spark is passed through it, and

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* Chem. News, lxvii, 39.

† Trans. Roy. Soc, 1884, 634.

L. Meyer and Seubert[*] observed at the same pressure that three-fourths of the gas combined. The writer noticed[†] that weak sparks did not cause an explosion of the gas. This is not peculiar to detonating gas, as Dixon[‡] states that "The explosion of cyanogen and oxygen depends solely on the nature of the spark. A strong spark causes the mixture to explode violently, whether wet or dry. A weak spark may be passed through the mixture, wet or dry, without apparent effect."

Emich[§] has recently studied the inflammability of thin layers of explosive mixtures of gases, and has found that the length of the spark required for ignition bears an inverse relation to the density, and that the addition of oxygen to detonating gas till it is to the hydrogen as 1 : 1 increased the sensitiveness of the mixture to sparks; an analogous fact obtains for an explosive mixture of hydrogen and chlorine. On the contrary, equivalent mixtures of carbonic oxide and oxygen are more sensitive than those containing an excess of either.

The glow discharge of electricity produces gradual combination of explosive mixtures.[||] Meyer and Raum[¶] experimented with detonating gas in sealed bulbs, and observed no perceptible combination after exposure for 218 days, to a temperature of 100°, while after 65 days, at 300°, they found in three tests that 9·5, 0·4, and 1·3 per cent of the gas had united. They obtained at 350° and 50 hours, 1·6 per cent, and after 120 hours, 1·9, 16·4, 0·5, 0·7 per cent. Krause and Meyer[**] found that 28 to 100 per cent of detonating gas combined when heated to 518° for 2 hours, in sealed bulbs. On the other hand, Askenasy and Meyer[††] observed that but little water was formed where the gas passed slowly through a vessel at 606°. Freyer and Meyer[‡‡] determined the temperatures at which mixtures of gases exploded when slowly passing through a hot vessel, and also when quickly heated in sealed bulbs. Explosions occurred at the higher temperatures given in the following table, but not at the lower:

		With free current.	In sealed bulbs.
Hydrogen	with oxygen required for complete combustion	650–730°	518–606°
Methane		650–730°	606–650°
Ethane		606–650°	518–606°
Ethylane		606–650°	518–606°
Carbonic oxide		650–730°	650–730°
Hydrogen sulphide		315–320°	250–270°
Hydrogen and Chlorine		430–440°	240–270°

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[*] Jour. Chem. Soc., xlv, 587.

[†] This Journal, iv. 51.

[‡] J. Chem. Soc., xlix, 384.

[§] Monatsheft f. Chem., xviii, 6, xix, 299.

[||] This Journal, iv, 51, 1897.

[¶] Ber. d. deutsch. Gesell., xxviii, 2804.

[**] Liebig's Ann., cclxiv. 85

[††] Liebig's Ann., cclxix, 49.

[‡‡] Zeitschr. für phys. Chem., xi, 28.

They also found that detonating gas suddenly heated in unsealed bulbs exploded at the same temperature as in sealed.

Before discussing chemical changes let us recall the condition of matter in gases—the molecules are moving very rapidly, some faster, some slower, an individual molecule moving in a straight line for a very short distance, until it strikes another. These collisions of one molecule with others are very frequent. The atoms composing a molecule are also moving in respect to each other, this motion constituting a portion of the internal energy of the molecules, which is continually diminishing through radiation. When the gas is heated the mean velocity of the molecules is increased, and at the same time the atomic motion and internal energy are also increased. At a sufficiently high temperature some of the collisions are so violent as to disrupt the molecules and their atoms part company.

When a mixture of gases is heated, chemical combination results from the encounters of different kinds of molecules having motion of translation, or of the atoms, or of both. At any given temperature the mean velocity of molecules may be calculated, but we have no data for determining at what greater velocity the molecular collisions are followed by chemical union. Polyatomic molecules are dissociated by heat, but since there is no measurable dissociation of hydrogen or oxygen at 1600° it does not appear that dissociation by heat plays much part in the change. Whatever the chemical changes caused by heat in gases, whether combination or dissociation, the condition necessary for these changes results from molecular impacts. If, for example, detonating gas be heated, a part of the molecules acquire a velocity and internal energy adequate for combination. Some of these encounter each other and combine to form water, the free atoms of oxygen uniting with each other or with hydrogen. The nascent water molecules have in general a high velocity, and collide with those of oxygen and hydrogen; but it is not probable that a single impact of a new water molecule with one of hydrogen or oxygen imparts to the latter energy adequate for combination. If it were so, the change would proceed with accelerating speed at a temperature of 300° to 500°. This view, that a nascent water molecule does not necessarily cause hydrogen and oxygen to unite, accords with that expressed by the writer,* that the heat of combination caused by the glow discharge of electricity does not produce further combination.

Why is it that chemical union proceeds slowly at 500°, and why does not the energy resulting from combination cause further combination, and thus raise the temperature of the system to the point of explosion? Let us suppose the mixed gases be heated from 500° to 501°. This increase in temperature will not cause them to explode. Assume further, that the heat of combustion during one minute is sufficient to raise the temperature of the gases 1°, provided no heat is lost by radiation. Experiments have shown that this rise in temperature will not cause explosion. But the gases heated by their own slow combustion continually lose heat by radiation, and hence are only slightly hotter than the surrounding medium. Were it possible to prevent loss of heat, the temperature would rise and the change proceed with accelerating speed.

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* This Journal, vi, 218, 1898.

The observations of Freyer and Meyer (loc. cit.), that explosive mixtures gradually heated have a higher ignition point than when suddenly heated, are difficult to explain, and further experiments may be useful. Their results also indicate that pressure is without influence, while A. Mitscherlich* found that at pressures less than one atmosphere the ignition point falls with the pressure. As pressure in so many cases influences explosion, it is remarkable in Freyer and Meyer's experiments that detonating gas in an open vessel, when quickly heated, exploded at the same temperature as it did under a pressure of two atmospheres or more. Mitscherlich's results also are the opposite of what we might expect.

Let us first consider the phenomenon of explosion of detonating gas at a low pressure when the combination is not complete. An electric spark or hot wire ignites the gas, the water molecules about the source of heat collide with the neighboring ones of hydrogen and oxygen, molecules of these elements being shaken up by many impacts and acquiring energy adequate for combination, and thus uniting and adding energy to the system. In this way the change propagates itself. A part of the molecules of hydrogen and oxygen have not combined. Why? When a denser gas is ignited, the combination is complete, and as the temperature of burning hydrogen is sufficient to dissociate water, we must assume that some of the water molecules are broken up, and as the temperature falls they reform, all of the hydrogen and oxygen uniting before the temperature is too low for combination. In the case of the rarer gas, the impacts to which a molecule of hydrogen or oxygen is subject from the nascent water molecules are less frequent than in the denser gas, and hence it is not as likely to acquire the energy needed for chemical union. Moreover, molecules possessing velocities adequate for combination encounter each other less frequently in the rare gas; hence the chemical change will proceed more slowly, and there will be more time for the system to lose heat by radiation. A molecule with internal energy adequate for combination loses this energy if its free path is relatively long; that is, given sufficient time though very brief, the molecule assumes a condition unfavorable to chemical union.

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* Ber. d. deutsch. Chem. Gesell., xxvi, 399.

Let us now see if other phenomena are explained by this hypothesis, considering first the case of an electric spark in detonating gas at a pressure too low for explosion. Here we have an enormous number of molecules combining in the luminous path of the spark. These radiate energy, part being electrical in its origin, i. e., a portion which was derived from the external work done upon the gas, and part resulting from chemical union. These encounter neighboring molecules of hydrogen and oxygen, imparting to some of them energy adequate for combination. Of these last a part combine, and we have now to consider a portion of gas consisting of water molecules, as well as those of hydrogen and oxygen. Some of the last named possess energy adequate for chemical union, but their encounters are too infrequent to restore by the heat of combination the energy radiated, hence the change proceeds with diminishing speed and finally ceases to propagate itself.

Feeble sparks do not explode detonating gas at a pressure of half an atmosphere or even more, but they cause slow combination. In this case it is not necessary to consider the possibility of the hydrogen carrying the electricity, since water molecules are formed, and we need only take into account a system made up of a relatively small number of nascent molecules of water, molecules of hydrogen and oxygen having energy adequate for combination, together with a relatively large number of molecules of these gases not having such energy. Under these conditions the impacts resulting in chemical union are too infrequent to maintain by the heat of their combustion the energy lost by radiation, and consequently the change does not propagate itself and cause an explosion.

Carbonic oxide and oxygen combine slowly at pressures less than an atmosphere when subjected to feeble sparks. Here too the impacts of molecules with a velocity adequate for chemical union are infrequent, as is evident from the fact that the change does not propagate itself.

In the case of cyanogen and oxygen either the feeble spark causes no chemical union, which is improbable, or as in the previous instances the change does not proceed throughout the gas because of the infrequency of impacts of high velocity molecules.

The study of the phenomena of explosives involves the thermal effect, but for the present purpose the heat evolved by the explosion or decomposition of equal volumes will suffice.

Two grams and 2 volumes of hydrogen burn with 1 volume o oxygen, with a thermal result of 58,700 calories, the produc gaseous; and 2 volumes of the mixture, therefore, give 39,134 c Likewise, 2 volumes of carbonic oxide and oxygen give 45,312 c.; 1 volume of hydrogen and 1 of chlorine give 22,000 c. and 24 grams of solid carbon and 2 of hydrogen unite wit an absorption of 48,170 c. to form 2 volumes of acetylene which evolves this amount of heat when resolved into it elements. In the same way, we have for cyanogen 65,700 c. for nitrous oxide 17,470 c., and for nitric oxide 21,575 c. se free when these compounds are decomposed into their elements The following table gives the resultant heat of the combination of equal volumes of three mixtures, and of the decomposition of four endothermic gases:

	Resultant heat.	Nature of product.
Hydrogen and oxygen	39134	Gaseous
Hydrogen and chlorine	22000	"
Carbonic oxide and oxygen	45312	"
Acetylene	48170	12/13 solid
Cyanogen	65700	12/21 "
Nitrous oxide	17470	Gaseous
Nitric oxide	21575	"

The molecular heats at constant volume of H_2, O_2, N_2, CO NO, and HCl are 4·2 to 5, and of N_2O, H_2O, and CO_2, abou one-half larger. Those of C_2H_2 and C_2N_2 do not appear t have been determined, but they are probably not greater tha 10. Evidently the molecular heats have little influence i determining the temperature at which explosion occurs, an the resultant heat does not account for the fact that the ignition temperature of chlorine and hydrogen is much lower tha that of hydrogen and oxygen, or of carbonic oxide and oxygen

Acetylene requires a pressure 20 times greater than detonating gas for explosion, while the heat of decomposition of the former exceeds that of chemical union of the latter. A temperatures not high enough to cause acetylene to separat completely into its elements or cause detonating gas to explode the two gases exhibit similar deportment in this respect namely, that the change is one of slow combination. Acetylene polymerizes to form C_6H_6, C_8H_8, and other condensation products, and detonating gas forms water. But acetylene when sparked under sufficient pressure, decomposes completely into carbon and hydrogen. The impacts of acetylene molecules with a certain velocity causes them to combine with each other, but when they have a higher velocity complete decomposition results. The change started by a spark in dense acety lene propagates itself throughout the gas. About the path of the spark there are sufficiently numerous encounters of molecules with a velocity adequate to cause decomposition, and the heat resulting is not lost by radiation before other molecules of acetylene are decomposed. Thus the change continues until only solid carbon and stable molecules of hydrogen remain. A proposed method for the commercial production of lampblack depends upon this fact. When, however, a spark passes through the gas at common pressure, the change occurs only in the path of the spark. Here the impacts of molecules with a velocity adequate to cause decomposition are more infrequent than in the denser gas—too infrequent, as the result shows, to propagate the change. The heat about the path of the spark is dissipated by radiation before it decomposes neighboring molecules. The infrequency of impacts allows sufficient time for radiation, and for the molecules to assume a stable condition. It is also probable that some more stable molecules, such as C_6H_6, are formed. If acetylene issuing from a tube is lighted, the decomposition does not extend into the tube for the same reason that it does not extend through the gas when sparked at ordinary pressure.

The deportment of acetylene under high pressure, when subjected to small sparks (p. 324) is similar to that of detonating gas.* Condensation products are formed in one case and water in the other. The minute spark imparts to the molecules of acetylene energy adequate to effect combination, and as the spark is visible we assume that the portion of the gas which is glowing has a temperature at which acetylene decomposes when larger quantities are heated. Thus the infrequency of impacts of molecules of high velocity is the real reason why feeble sparks do not start an explosion in dense acetylene.

The non-explosion of cyanogen (p. 325) under high pressure when sparked, although it is more endothermic than acetylene, is doubtless connected with the fact that it requires a higher temperature for its decomposition than the latter; or it may be that the union of CN with CN is exothermic, while the radical itself is endothermic. Nitrous oxide and nitric oxide are stable at high temperatures and these also do not decompose with explosive violence when sparked under pressure. It is probable that all three of these endothermic gases would explode if sparked under pressure and at a temperature approaching that at which they dissociate.

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* This Journal, iv, 51.

Recapitulation.

Detonating gas, a mixture of carbonic oxide and oxygen, one of cyanogen and oxygen, and other explosive mixtures of gases do not explode below certain pressures when sparked: and the decomposition of acetylene does not propagate itself at pressures less than two atmospheres. In the path of the spark chemical changes occur which do not extend throughout the gases, and the same is true of a weak spark in the gases mentioned when under a pressure at which a strong spark explodes them. It appears for reasons already stated that explosions do not occur in the instances given only because of the infrequency of impacts of molecules having a velocity or internal energy adequate for chemical union. In the rare gas the impacts are less frequent than in a dense gas, the mean free path is longer, and there is more time for a molecule with energy adequate for combination to lose this energy by radiation and to attain a condition unfavorable to chemical union. Some of the molecules combine, but the heat of their union is not sufficient to restore the energy lost by radiation and the change is therefore not self-propagating. The same explanation holds good for the phenomena of feeble sparks in a dense explosive gas where in the path of a spark there are relatively few molecules with energy adequate for combination, and these collide with each other less frequently than with the molecules not having such energy. In a dense gas a given quantity and a degree of heat, that is, sufficient frequency of molecular impacts, is requisite to secure spontaneous extension of the change.

ART. XXXVI.—*On the Occurrence of Paleotrochis in Volcanic Rocks in Mexico;* by HENRY S. WILLIAMS.

Introductory Note.—This article was written, Nov. 22, 1897, at the time of the study of the specimens sent by Dr. Dugès, but for various reasons was not then published. A discussion in the Geological Society last December led the writer to refer to these specimens as proof of the non-organic nature of Paleotrochis. Later the Mexican specimens, together with the manuscript copy of this paper, were sent to Mr. Walcott and then to Mr. Diller in confirmation of the inorganic origin, and association with igneous rocks, of Paleotrochis. It is thought best to publish these facts for what they are worth, in connection with Mr. Diller's thorough study of the subject as presented in the following paper.

SOME specimens sent to Yale College for identification, by Dr. Alfred Dugès of Guanajuato, Mexico, throw some light upon the nature of the peculiar forms described by Emmons under the name of Paleotrochis. The specimens come from what appears to be an old eroded volcanic cone made up of "Porphyre altéré," "Peckstine rouge" and volcanic tuffs, situated northeast of Guanajuato in the Santa Rosa Mountain range. Among the specimens are several fragments of much altered fragmental as well as massive volcanic rocks. One specimen is filled with amygdules.

The majority of the specimens are composed of milky quartz of the shape called Paleotrochis by Emmons, with variations in form which are particularly suggestive. These suggestive variations are the imperfect form, one-sided, or as if made up of several of the conical halves of typical paleotrochis joined together at their bases, some of the cones being very broad and nearly flat, but each having the appearance of accretion from the small end which in the lower cones is near the center. When thus nearly flat the lines of concentric accretion are evident, while the cones with less angle of slope show the radiating lines more conspicuously. The suggestion furnished by their study is that they were formed in a manner similar to that of the formation of ice columns under a loose soil, which at about freezing temperature sometimes grow to several inches in length. The lengthening of the column of ice, in the latter case, appears to be due to additions of ice forming as soon as the cool atmosphere is reached, while the temperature of the soil is still enough below freezing to permit the water to be drawn up by capillary flow to the surface as the freezing removes it from the surface immediately below.

In the case of the Paleotrochis the application of the suggestion would be in this wise: If a porous rock, had arising through it from below, superheated waters carrying solution of silica, a point might be reached when suddenly the looseness of the rock would permit of rapid radiation upwards of heat, while below the temperature of the heat would be high and remain nearly constant for a long period. Such conditions might occur along the plane of a considerable exit of the rising waters, the rocks below being saturated with the heated waters and above the rock being more or less open by the absence of water. I conceive that, at the junction, a condition might occur in which silica would begin to deposit on the interior of a cavity, but the supply of silica, or of silicated waters, would be furnished only as it was abstracted by solidification. Thus at the points where solidification began the cavity would be increased by the crystallization, and into this cavity more silicated waters would arise; thus the accretion-surface would increase with the lengthening of the cone by the separation of the apices of the cones; consolidation taking place at the point of meeting of the solidified silica with the water, and the water reaching that point slowly.

If some such explanation be the fact, the association of these peculiar forms with gold is explained. Also that such conditions should occur in volcanic regions and particularly in the midst of volcanic tuffs, as in the Mexican case, is as would be expected.

Nov. 22, 1897.

ART. XXXVII.—*Origin of Paleotrochis;* by J. S. DILLER.

PROF. EBENEZER EMMONS,* while State Geologist of North Carolina, discovered among the so-called Taconic rocks of Montgomery County, in that State, a number of more or less regularly striated bi-conical forms to which he gave the names Paleotrochis major and minor, and regarded them as siliceous corals as well as the oldest representatives of animal life upon the globe. According to Emmons Paleotrochis varies in size up to two inches in diameter, and occur with many almond-shaped concretions, often within concretions, in a series of beds over 1,000 feet in thickness interstratified with beds of granular quartz, conglomerate and quartzite. Both species of Paleotrochis have the form of "a flattish double cone applied base to base" with the surfaces grooved somewhat irregularly from near the apex to the basal edge. The smaller form, P. minor, has the "apex of the inferior side excavated or provided with a small roundish cavity" and the other apex "supplied with a small rounded knob, from the base of which the radiated grooves begin." The larger form, P. major, "differs from the foregoing (P. minor) in the absence of the roundish apical depression of the lower side and the knob of the opposite side."

Prof. Emmons regarded Paleotrochis not only as originally siliceous but also gemmiferous, thus accounting for knobs as well as irregular adhering groups, and it is important to note that he reports "these fossils also occur in a variety of quartz or quartzite which I have described as a buhrstone, and which is often porphyrized."

Prof. James Hall,† after an examination of many specimens, regarded the Paleotrochis of Emmons as nothing but concretions in quartz rock. Prof. O. C. Marsh‡ examined the forms microscopically and found them composed of fine-grained quartz, but no trace of organic structure could be detected. While maintaining its inorganic nature he regarded it as difficult to explain, and considered it as having some analogy with cone-in-cone, which he thinks is probably due to the action of pressure on concretionary structure when forming.

The most extensive paper on this perplexing form is that of Mr. C. H. White,§ who strongly advocates the organic nature of Paleotrochis. The specimens he examined were those obtained by Prof. Emmons, as well as a number collected by Prof. J. A. Holmes, the present State Geologist of North Carolina. Mr. White describes in detail not only the peculiarities of the weathered surface of the rock but also the features exhibited upon a fresh fracture, and called attention for the first time to the radial fibrous mineral which he regarded as impure chalcedony. According to Mr. White, the fossil forms are enveloped in chalcedony and the small concretions are made of the same material.

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* Geological Report of the Midland Counties of North Carolina, 1856, page 62, also this Journal, II, vol. xxii, page 390, and vol. xxiv, page 151.

† This Journal, II, vol. xxiii, page 278.

‡ This Journal, II, vol. xlv, page 218.

§ Journ. of the Elisha Mitchell Scientific Soc., Chapel Hill, N. C., Part 2d, July to December, 1894, pages 50–66.

In 1887, Prof. J. A. Holmes* visited the Sam Christian Gold Mine of Montgomery County, N. C., and studied the Paleotrochis-bearing rock in the field. Although he had not then seen any of the acid volcanic rocks from New England, described by Dr. M. E. Wadsworth, or from the South Mountain region of Maryland and Pennsylvania, subsequently described by Dr. G. H. Williams and Miss Florence Bascom, he was of the opinion that the rocks in the neighborhood of the Sam Christian Gold Mine were of eruptive origin. Later observations have convinced him of the correctness of this view. The same opinion is entertained by Messrs. H. B. C. Nitze and George B. Hanna,† who consider the Paleotrochis-bearing rocks at the Sam Christian and Moratock Mines as ancient acid volcanics, and state that "it appears highly probable that at least some of these siliceous pebbly concretions are spherulites." Unfortunately in the preparation of their report time did not permit the authors to study thin sections.

The specimens which, at the request of Mr. C. D. Walcott, the Director of the U. S. Geological Survey, the present writer has had an opportunity to study, consist of a small collection‡ from Mexico sent by Prof. H. S. Williams, besides three fragments about nine inches in diameter sent by Prof. J. A. Holmes, who collected them in 1887 at the Sam Christian Gold Mine, North Carolina, and from the same place several dozen of the original specimens of Paleotrochis major and minor collected by Prof. Emmons. Specimens of the rock and isolated fossils, excepting those from Mexico, have been cut and polished and thin sections prepared for microscopical study.

The rock from North Carolina which contains Paleotrochis is full of nodules of various shapes and sizes, ranging from that of a pin's head to nearly two inches in diameter. These are the supposed concretions and fossils. Upon a fresh fracture the rock appears to be composed chiefly of quartz, but when weathered most of the nodules become white as if kaolinized, while the other nodules and the matrix remain quartzose in appearance. The nodules form at least two-thirds of the mass of the rock and are arranged with their longer diameters parallel, rendering the rock rather easily split in one direction.

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* Letter to the author Feb. 6, 1899.

† North Carolina Geological Survey, Bul. No. 3, pages 37 and 39.

‡ See Prof. William's article, this volume, page 335.

With a lens, it may be seen that the small kaolinized nodules exposed in section upon the surface of a hand specimen have a radial fibrous structure. The same structure may be seen in some of the larger ones, and in addition to this feature some of the nodules possess a more or less distinct concentric shell-like structure. These structures are usually best displayed upon or close to a weathered surface. Portions of the nodules or spaces between them are in a few cases cellular, and the walls of the openings are rarely lined with minute crystals. The supposed fossil forms usually appear conical or discoidal upon a weathered surface. They often show a small cup in the apex and are surrounded by a narrow depression from which the radial fibrous envelope pointed out by Mr. White has been removed by weathering.

A careful comparative study of the nodules in the hand specimens tends to convince one that however different in form and size the supposed fossils and concretions may appear, all belong to one series and have essentially the same origin.

A microscopical study of thin sections of the rock reveals the fact that the nodules are spherulites, a common feature of acid igneous rocks. They are composed in most cases chiefly of fibrous feldspar with quartz or tridymite. As seen in the thin section of the Paleotrochis-bearing rock, the fibers are grouped radially with more or less irregularity in tufts, sheaves, sectors, hemispheres or spheres. When they form a complete sphere, which is rarely the case, they are most coarsely fibrous or granophytic at the center and usually show between cross nicols an indefinite black cross. Occasionally also the concentric structure is well marked. The rays are too minute to permit of an accurate determination of their mineral composition by optical methods, but microchemical tests with hydrofluosilicic acid yield the small cubic crystals, characteristic of potassium fluosilicate as well as the hexagonal prisms of sodium fluosilicate. Judging from the greater abundance of prisms than cubes the fibrous feldspar is richer in sodium than potassium. That feldspar, instead of chalcedony, is the most prominent constituent of the spherulites, is fully borne out also by its kaolinizing under the influence of the weather.

The spherulites are embedded in a matrix composed chiefly of granular quartz. The grains are occasionally so large that the uniaxial positive character can be readily determined. Untwinned feldspar in small grains may be present in considerable amount and yet be easily overlooked. The quartzo character of the weathered matrix, however, shows that least where most coarsely granular there cannot be much any feldspar present in it. In places the matrix contai numerous minute parallel scales of what appears to be sericit Associated with the most coarsely crystalline areas are a fe scales of brown biotite and occasionally considerable gre biotite, which in places is so abundant as to make quite prom nent dark green spots. Both matrix and spherulites are tra ersed in a few cases by small veins of granular quartz, showi that there is a considerable amount of secondary quartz prese Both spherulites and matrix are rendered slightly micropo phyritic by containing occasional crystals of plagiocla feldspar and quartz. The plagioclase, which, on account its small angle of symmetric extinction, must be an acid o in some cases forms the center from which the spherulit fibres radiate.

An isolated specimen of Paleotrochis was cut through t apices and found to be composed of granular quartz. T quartz was fine-grained upon the outside where the grains we set with their longest axes perpendicular to the adjoining s face. The middle portion contained an irregular iron-stain cavity possibly due to the disappearance of some iron-beari mineral. Several of the half embedded forms of Paleotroch were cut in a hand specimen to discover its relations to t enclosing rock, and in each case it formed the interior porti of a spherulite. Most of them contained a dark green patc The exposed conical surface of one was well striated and the was an irregular depression in the apex. The form was co posed chiefly of granular quartz with a yellowish brown dark green, strongly pleochroic biotite. Near the center is small spherulite which is not only bordered by finer-grain quartz but is cut by a small vein of it, showing that the dep sition of the quartz is subsequent to the development of t spherulite. The embedded portion of Paleotrochis is border by spherulitic fibers which run approximately parallel to t slope of the conical surface, and it is evident that the casts these fibers produce the irregular striæ or grooves upon t surface of the supposed fossil. The embedded portion term nated with an irregularly-pointed apex below. The who form is fine-grained near the border and sends small veins in the adjoining spherulitic shell. These veins are so small as n to be visible upon a polished surface of a hand specimen eve with the aid of a pocket lens, but come out distinctly in t thin section. The spherulitic shell by which Paleotrochis enveloped is composed of fibers belonging to a number centers or lines and yet combined they appear to form o nodule. The biconical form of Paleotrochis suggests that it originated as two spherulite sectors of which the apices were the centers from which the fibers radiated. This would seem to be the simplest way to account for the most regular as well as many of the irregular forms, but of the specimens examined I have not been able to find one that certainly originated in that way.

A number of the fossil forms with a well-marked cup in the exposed apex turned out to be flat hemispherical or thin lenticular in section, and are composed wholly of spherulitic fibers.

Although admitting much irregularity especially on account of the supposed gemmiferous character of Paleotrochis, the ones which have been considered the most characteristic of the fossil are the distinctly biconical forms. These so far as seen are chiefly granular quartz with more or less green biotite.

It is important to note also that the dark groups of green biotite occur in the interior of very irregular nodules which have no suggestion in them of Paleotrochis. Irregular flattened lenticular masses of granular quartz with green biotite occur within the spherulites as well as about them. The green mica is found only in the most coarsely granular groups of quartz.

The following chemical analysis, made by W. F. Hillebrand, shows that the rock has the composition of a rhyolite and accords closely with the results of the microscopical study.

Analysis of the Paleotrochis-bearing rock of Sam Christian Mine.*

SiO_2	79·57	
TiO_2	·11	
Al_2O_3	11·41	with a very little P_2O_5
Fe_2O_3	·20	
FeO	·70	
MnO	none	
CaO SrO	·21	
BaO	·05	
MgO	a very little	
K_2O	3·52	
Na_2O	3·46	
H_2O below 105°	·18	
" above "	·61	(ignition)
	100·02	

Recognizing the Paleotrochis rock as an acid volcanic full of spherulites, it is easy to understand the great variation in the form of the nodules. Such rocks are in many places distinctly banded and were long considered siliceous sediments, but by the investigations of Wadsworth, Williams, Bascom and other it has been definitely settled that they are all acid volcanics These rocks in North Carolina are regarded by Mr. Holme as pre-Cambrian and since their eruption may have undergon great changes like those of the South Mountain described b Miss Bascom. Some of the supposed fossils are certainl spherulites, and all of them may have been originally. Som broken forms show motion in the mass after the spherulite were developed. That Paleotrochis where most perfectly developed and composed of granular quartz is the result o deposition, after the spherulitic growths about it and within i had developed, there can be no question, but whether this deposition followed soon after that of the spherulites in the cours of solidification or took place in hollow spherulites (lithophysæ or resulted perhaps long subsequently at the time of rock alterations, is not so clear. All this and much more will doubtless b cleared up by the members of the Geological Survey of Nort Carolina, who were the first to correctly identify the rock an the character of the supposed fossil.

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* No other constituents looked for.

None of the Mexican specimens received from Prof. Wi liams were cut for microscopical examination. Some of the were clearly of igneous origin, and contained amygdules. Th Paleotrochis-like forms with radial markings appeared to b composed of secondary quartz and probably originated as thos of North Carolina.

About a year ago bi-conical forms like Paleotrochis were pr sented by Mr. Kochibi, Director of the Geological Survey o Japan, to the U. S. Geological Survey. These specimens ar now in the National Museum, and are much more regular i form, size, and general appearance than the Paleotrochis o North Carolina. They are of a pale pink color with regula bi-conical, striated forms, and in some cases have shallow pi in one of the apices. They are known in Japan as "Soroba ishi" or abacus stones. One of these specimens contains small fragment of the rock from which these curious specime were obtained, and it appears to be spherulitic. According t Mr. Willis, who obtained the information directly from M Kochibi, "these stones are found only in rhyolitic tuffs. The not infrequently occur much larger than these specimens, po sibly up to two inches in diameter or more, and are more fr quently associated in groups of two or three overlapping o coalescing. They are generally white, the rosy tint of thes specimens being a rare characteristic." A thin section of on of these "abacus-stones" shows it to be an agate of which th outer layers are pink and the inner white. There can be n doubt in this case that the form resulted from the filling of th cavity long after the solidification of the igneous material.

U. S. Geol. Survey, Washington, D. C., March 3, 1899.

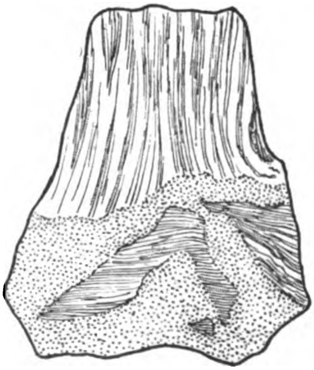
ART. XXXVIII.—*On the Association of Argillaceous Rocks with Quartz Veins in the Region of Diamantina, Brazil;* by ORVILLE A. DERBY.

IN a recent excursion in the region about Diamantina, Minas Geraes, Brazil, the frequent association of the decomposition products of argillaceous rocks with the quartz veins with which the underlying metamorphic series of the district is threaded attracted attention. The phenomenon was the more striking because of its absence in a long stretch of road over a newer series in which quartz veins are equally if not more abundant.

The most frequent appearance is that of a selvage to the veins and of intercallations in the mass of the quartz of a reddish foliated clay apparently resulting from the decomposition of a micaceous rock. Less prominent in the surface exposures but quite frequent in the artificial openings that have exposed the inner portions of the veins, are nests and stringers of a structureless white clay (kaolin) that may be either farinaceous or indurated (lithomarge). The red clay was observed in a sufficient number of instances to warrant the assertion that it is a general, if not a universal, feature of the quartz veins of the region and that when it occurs it is constant throughout the entire extension, both lateral and vertical, of the vein. The distribution of the white clay, on the other hand, is patchy and considerable portions of a vein in which it is known to occur may be free from it.

A magnificent exposure of a vein of this character is afforded by the eastern wall of the great cutting of the diamond mines of São João da Chapada, of which an excellent view, reproduced from a photograph, is given in Boutan's monograph on the diamond (Encyclopèdie Chemique de Fremy), and in a recent paper by the present writer in the Journal of Geology (vol. vi, p. 121). Contrary to the description previously given, based on a rapid examination made under unfavorable circumstances and with a limited experience in the identification of decomposed material, this cutting is made along the junction of a conglomeritic diamond-bearing quartzite, and an older fine-grained quartzite (itacolumite), both being profoundly decomposed and in many places indistinguishable except on the closest scrutiny. The eastern wall, which on account of its inaccessibility in the wet season, when it is defended by a frontage of quicksand, and of its superficial staining from the highly-colored overlying soil-cap has been described as a complex of various schists, proves to be a uniform mass of itacolumite with only a single argillaceous member that presents in a striking manner the above-mentioned association with vein quartz. Throughout the entire length of the cutting, a distance of over 500 meters, runs a sharply-defined layer from 1 to 2 meters thick of argillaceous material with quartz which has received from the miners the name of *Guia* (Guide), because, as they state, diamonds were to be looked for below (or in front) and not above (or behind) the outcrop of this layer.

This layer consists principally of a mass of dark red foliated clay which is evidently a decomposed schist stained with oxide of iron. In several places that afford access to its interior, the central portion is seen to be occupied by an irregular but apparently continuous mass of vein quartz, that sometimes swells out so as to occupy half or more of the thickness of the layer, being in other places reduced to a thickness of a few centimeters only. Associated with the quartz is a pure white granular kaolin which in places is intimately mixed with small angular granules of quartz in a way that suggests a decomposed granite, but in general forms pockets or a selvage in or around the more massive portions of the vein. Outside of the kaolin, when this forms the marginal portion of the vein, or inclosed as angular fragments in its mass, is a minutely banded reddish, or yellowish, micaceous clay that appears to differ from the red clay composing the greater part of the mass of the Guia only in the absence of the intense staining with oxide of iron. The relations of the white kaolin with the banded clay is well shown on the scraped surface of a block that was brought away, and represented about one-fourth the natural size, in the accompanying figure, in which the dotted portion represents the granular white kaolin and the shaded portion the banded clay. The unshaded streaks in the latter are also of white kaolin that differs from that of the vein in the less distinct granulation, but which in places, as at the lower right hand side, appears to be flame-like apophyses from it.



A very pure specimen of the granular kaolin kindly analyzed by Dr. Hussak gave: SiO_2 44·96 per cent, Al_2O_3 42·09 per cent, H_2O 13·25 per cent. This composition differs from that of a typical kaolin derived from a feldspar only in a slight excess of alumina which may perhaps be due to the precipitation with it of rare elements that are known to occur in the clay.

The quartz and kaolin are so blended that they must be considered as constituting a single geological body, and this can hardly be else than a rock of original granitic, or rather pegmatitic type. Moreover this body from the character of its contact, as shown in the figure, must have been eruptive. The character of the accessory elements is in accord with this view. Those that appear macroscopically are rare prisms of red rutile and handsome tabular crystals and groups of specular iron. The heavy residue obtained by washing is in parts very small, in other parts (where rutile abounds) very abundant, and with the appearance of being wholly authigenetic. It consists principally of rutile partly in rather large sagenitic groups of octahedral form that are evidently pseudomorphs after some mineral of the regular system (possibly titaniferous magnetite) with extremely rare grains of anatase, magnetite, tourmaline and xenotime. The latter is in beautiful glassy prisms with short pyramidal terminations of rather large size that show a tendency towards crystals of macroscopic dimensions such as occur rarely in the concentrates of the mine. The rutile and anatase are evidently secondary, and of the presumably primary accessories, magnetite, tourmaline and xenotime, the latter is the most significant as thus far it is only known *in situ*, at least in Brazil, as an extremely constant and characteristic accessory of the ultra-acid (muscovite) granites and pegmatites. The absence (at least apparent, as in order to avoid admixtures only small quantities could be washed) of its almost constant companions, zircon and monazite, is noteworthy. In this connection it may be recalled that in a recent paper by Dr. Hussak,* on an auriferous quartz vein in the same series near Ouro Preto, these three characteristic granitic accessories were found together, and from this circumstance and from the occurrence of characteristic contact minerals the same conclusion was arrived at, viz.: that the vein is an ultra-acid phase of a granitic apophyse.

The colored clays of the Guia present the appearance of the decomposition products of a micaceous schist. As already stated, the distinct banding of white and colored portions, such as is represented in the figure, in the parts next to the quartz-kaolin vein, is probably due to minute interlaminated projections from the latter, and in support of this view is the fact that the white bands are distinctly kaolinitic (though not granulated like the kaolin of the vein), while the colored ones are as distinctly micaceous. Aside, however, from these distinct white bands, there is an obscure lamination visible even in the most highly-stained portions. On a carefully scraped surface cut transverse to the lamination a few scattered rounded eyes of quartz are in some portions visible, which with the banded structure are very suggestive of a stretched quartz porphyry. These eyes occur both in the dark red clays and in the lighted colored ones, but are much more abundant in the latter than in the former. This fact taken in connection with the increased staining of the clay towards the margins of the mass and the apparent lack of a physical break between the lighter and the darker colored clays may, perhaps, be taken as an indication that the original rock was more acid in the central and more basic (or at least richer in iron) in the marginal portions of the mass.

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* Zeitschr. f. prakt. Geol., Oct., 1898.

On washing, both the dark and the light colored clays give, after a considerable loss as slime, an abundant residue of white micaceous aggregates (in the case of the red clay treatment with acid is necessary) with the aspect of sericite with rare granules of quartz that appear to come exclusively from the eyes. On separation of the mica and quartz by washing or the use of heavy liquids, we find an extremely abundant residue of mixed rutile and anatase (sometimes the one, sometimes the other predominating), which appear to come from original ilmenite represented by abundant black grains in the red and by rather rare, dirty aggregates of ill-formed anatase or rutile in the lighter colored clay. With the titanium minerals occur rarely minute prisms of tourmaline and prismatic fragments, rarely perfect crystals, of monazite of the peculiar type to be described farther on. All the elements of the residue are distinctly authigenetic and in this respect are in marked contrast with those of the adjoining quartzite, which with the same titanium minerals (with the exception of ilmenite) and tourmaline in perfectly fresh crystals contains an abundance of well-rolled zircons.

The Guia is thus a composite body that consisted originally of a vein, or dike, of a quartz-feldspar rock, presumably pegmatitic granite, injected into a micaceous schist that may have been originally either a sedimentary shale or a sheared eruptive. The appearance of the mass is exceedingly dike-like, but if a dike, it must have been injected along a bedding plane, or so nearly coincident with one as to simulate an intercallated layer. The characters above given of apparent porphyritic structure, absence of distinctly clastic elements, and the presence of monazite, all favor the view of an eruptive origin and appear to be of more weight than those of schistose structure and apparent interbedding with the quartzite which are the most important that can be cited in favor of the opposite view. This question will be discussed farther on.

For an attempt to reconstruct the original rock of the colored portion of the Guia we have the positive indications of a schist free or nearly free from quartz and rich in sericite (or a micaceous mineral resembling it which for convenience will be called by that name), with an abundance of iron and titanium minerals, tourmaline and monazite, as characteristic primary accessories and with an entire lack of distinctly clastic elements which in a series with the degree of metamorphism of that about Diamantina could only be rolled zircons or regenerated tourmalines.* For the purpose of attempting such a reconstruction, specimens were collected of such rocks as from their general aspect might be suspected of representing the original type from which the Guia clays might be derived. From the numerous specimens examined from various localities, the comparative freedom from quartz and the abundance of sericite, of iron and titanium minerals and of tourmaline prove to be common characteristics of the phyllites of the region, which can only be distinguished as presumably original sedimentaries or eruptives by the presence or absence of distinctly rolled zircons (often of a size and abundance that seems extraordinary in rocks presumed to represent fine-grained sediments) and of monazites or zircons, or both, with the aspect of original primary accessories.

The rock which from its position and aspect seemed to be the most promising was a partially decomposed greenish schist found in loose blocks at the foot of the western wall of the cutting, and which, judging from appearances, was thought to have fallen from a layer somewhat similar to the Guia and only a few dozens of meters below it in the same geological series. This, however, proves to be characterized by an abundance of well-rolled zircons and of regenerated tourmalines and by an entire absence of monazite.

Another rock from the immediate vicinity and presumably from the deep rock cutting (mainly in hard itacolumite) for the drainage canal of the Duro mine (seen in the background of the above cited figure in the Journal of Geology), is a thoroughly sound, bluish, imperfectly laminated phyllite of which numerous blocks have been built into a wall at the mine-house. Some blocks have in the joint planes handsome plates of specular iron like those of the Guia clay. The rock is for the most part mottled with large yellowish blotches suggestive of enclosed crystals or pebbles, and on a polished cross section shows a minute banding with sheared eyes, corresponding to the blotches, suggestive of a sheared porphyritic rock. The most massive specimen shows evidence of shearing in two planes nearly at right angles to each other, and, in this, part of the original structure which, in the most of the specimens, has been obliterated by the two systems of shearing can still be observed. The appearance under the lens is that of an altered diabasic rock sheared to the point of obliterating the rectangular outlines of the feldspars without completely destroying them. The spots above referred to have the aspect of phenocrysts of feldspar that have lost something of their sharpness of outline. Microscopic sections show a general sericitic mass blackened in irregular bands and patches with a fine dust of iron ores which on being dissolved with acid leave whitish aggregates of a titanium mineral (anatase?). The heavy residue consists of a great abundance of iron and titanium minerals, the latter only rarely showing well-defined forms of rutile and anatase. The only other elements recognizable are rare grains of tourmaline and small prismatic fragments, rarely perfect crystals, of monazite. Some of the grains referred to this mineral may possibly be zircon, but if so they are perfectly fresh (not rolled), but indistinctly characterized. The original rock was apparently a basic eruptive very rich in iron and titanium minerals (ilmenite?) and with rare phenocrysts of the more acid element. So far as can be made out, this rock would on decomposition give exactly the characters of the red clay of the Guia. The principal difficulty in the interpretation of this rock and of the red clay of the Guia as a sheared and metamorphosed basic eruptive is the presence of monazite, which thus far is only known *in situ* in the acid eruptives or their metamorphosed representatives.

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* See Derby, On the accessory elements of itacolumite, etc., this Journal, March, 1898. In this paper it was suggested that the lazulite that occurs quite frequently in the quartzites about Diamantina might have been derived from original clastic phosphates. This view is confirmed by an examination of more abundant material in which distinct but partially altered and corroded monazites and xenotimes were found in the heavy residue of nodules rich in secondary lazulite.

Two other rocks from the same region present certain characteristics in common with the one above described and if, as seems probable, they can be genetically connected with it, will serve to establish a graduation into a more acid type on the one hand (thus removing in part the difficulty above noted), and on the other hand into a better-defined basic type. From near the Serra do Gigante, several miles to the northward of São João da Chapada on the road from Diamantina to Grão Mogol, my friend and companion, Dr. Francisco de Paula Oliveira, brought a loose block of a peculiar cyanite-phyllite full of enormous crystals of cyanite in an imperfectly laminated groundmass of sericitic appearance. The rock is free from iron ores, but extremely rich in minute aggregates of rutile and of extremely minute prismatic needles that are referred to monazite. The original rock was evidently a highly aluminous (feldspathic) one, with an abundance of a titanium mineral (ilmenite?) and of monazite, in which through shearing and the development of secondary minerals, all traces of the original structure has been obliterated. A very similar rock, but lacking the monazite, was found by Dr. Hussak on the Ilha do Fogo in the river São Francisco in front of the town of Joazeiro, where it presents the aspect of a dike in gneiss.

Some 15 or 20 miles to the southward of São João da Chapada, near the fall of the river Dattas close by the town of Gurvêa, another imperfectly laminated phyllite was found outcropping in the road that strongly resembles that of São João but differs principally in the absence of monazite, in the preservation of the original rectangular outlines of the white mineral transformed into sericite, and in the great quantity of tourmaline that is evidently an element introduced in the metamorphism of the rock. In addition to the fine iron dust that on removal by acid leaves a dust of formless aggregates of titanium, the rock contains magnetite in considerable-sized grains and octahedral aggregates of an altered titanium mineral that strongly resembles those of decomposed perofskite described by Hussak from the diamond gravels of Agua Suja (Neues Jahrb., 1894, ii, p. 297). Judging from the sharply cut rectangular outlines of the areas of sericite free from the iron dust, the original rock must have been largely composed of lath-shaped crystals like those of the plagioclase or melilite of diabasic or basaltic rocks, and with this conclusion the great abundance of the iron and titanium dust, that may be presumed to come from original ilmenite, and of magnetite with an octahedral titanium mineral, is in accord. The shearing has not been sufficient to obliterate the form of the white element and appears to have been anterior to the introduction of the tourmaline that lines the joint planes and has invaded many of the rectangular sericitic areas without passing beyond their limits.

There can be no reasonable doubt but that the rock last described is a metamorphosed and moderately-sheared basic eruptive and when it is recalled that "mixed dikes" have been described (see Zirkel, Petrographie, i, p. 784) in which a granite-porphyry passes to a type that has been described as diabase or melaphyre, the hypothesis that the two rocks above described and the decomposed material of the Guia may be genetically related is not so extravagant as at first sight appears.

The most serious objection to bringing the Dattas rock into line with the others is the absence of monazite, but in regard to this it may be noted that this mineral (like the xenotime in the white kaolin) is so rare that it failed to appear in some of the tests made.*

The association of argillaceous material with quartz veins is also a prominent feature in the diamond mines about the little village of Sopa, about a dozen kilometers to the southward of São João da Chapada. The diamond-bearing material is here a decomposed conglomeritic quartzite entirely similar to that now on view in the mines of São João.† This rests unconformably on an older series of quartzites (itacolumites) with intercallated schists that is also profoundly decomposed. This lower series is abundantly threaded with small irregular quartz veins that frequently show included pockets and stringers of indurated kaolin and almost invariably partings and selvages of various colored schistose rocks or clays that closely resemble those of the Guia above described. The white kaolin which is less abundant and constant than in the Guia, affords the same residue of rutile and anatase with rare prismatic grains of xenotime. In a washing from the kaolin of the Bambá mine the residue, consisting almost exclusively of anatase with some grains approaching a macroscopic size, was nearly 0·05% of the quantity washed. In another from Misael's mine the residue is scanty, as in the greater part of the tests from the Guia, and consists principally of rutile with rare grains of anatase. In both the xenotime is in rare individuals, mostly in fragments, of comparatively large size showing a tendency to assume macroscopic proportions.

The schistose accompaniment of the veins at Sopa is, in the few cases observed in which it is well preserved, a well laminated, almost papyraceous, micaceous greenish schist that gives on decomposition an ash-colored, or reddish, clay, not distinguishable, except by its residue, from the clays derived from the phyllites intercallated in the series in which the veins occur. A large "horse" left standing in the center of Misael's mine, and decomposed to a yellow ocherous clay, shows to the naked eye abundant pyrite (altered to limonite) and tourmaline, and affords on washing a very slight residue of quartz, much tourmaline in handsome prisms, and a comparative abundance of well-rolled zircons with rare grains of rolled rutile and still rarer ones of sagenite that, like the tourmaline, appear to be authigenetic. An ash-colored clay poorly exposed, only a few meters away and of very similar aspect, affords an entirely different residue characterized by an extraordinary abundance of minute sharp-angled prisms of monazite of peculiar type, with rare tourmaline and still rarer octahedral xenotimes often intergrown with zircon but altered to a yellowish mass that is difficultly distinguishable from the aggregates of titanium minerals so abundant in the various rocks of the region. There is here a complete absence of rolled zircon or of other elements that can be considered as allothigenetic. Specimens from two distinct outcrops of the green schist associated with quartz veins in the immediate vicinity of the mine show, along with much rutile that is evidently of secondary origin, a mixture of the characteristic elements of the two clays above described, that is to say, perfectly sharp crystals of monazite with well rolled zircons, both in considerable abundance. A polished cross-section of one of the more massive pieces of this schist shows a banded structure with alternations of a dark green with an ash-colored material. The two are so intimately interlaminated that they could not be completely isolated so as to give perfectly unmixed residues, but there is an evident concentration of monazite in the green and of zircon in the lighter-colored portion. Thus both the character of the residue and the aspect of the specimens indicate that this schist has been produced by the shearing and metamorphism of a mass of mixed material of which one part, corresponding to the "horse" of the neighboring mine, is characterized by allothigenetic zircons and the other, corresponding to the other clay of the mine, by authigenetic monazite. Thus the veins at Sopa appear to be highly-sheared bodies essentially identical with the Guia but more completely mingled with the adjoining rocks.

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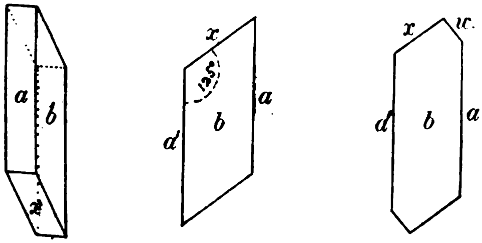
* Owing to this circumstance, and to the difficulty of avoiding admixtures, the tests of the material from the Guia in which the rare accessories proved to be infrequent and inconstant, were many times repeated and with special precautions. The identification based on form, optical properties and behavior with heavy liquids was confirmed by microchemical tests for phosphoric acid and for cerium and yttria.

† The question of the diamond in these deposits will be discussed in another place. The conclusion presented in former papers, that the gem occurs in vein material, was based on the examination of a mass shown me in 1880 as a diamond-bearing body, but which I am now convinced was a detached section of the Guia, in which, according to the best obtainable information of the present day, no diamonds have been found, and which presents no evidence of having been worked. On the other hand, it is certain that one of the diamond-bearing bodies not now visible was closely similar to it in appearance, though perhaps not in original character and origin. The section of the Guia examined in 1880 was much richer in tourmaline than the parts washed on the recent visit.

The observations above recorded indicate the presence in the older series of the region of dikes of a rock characterized by titanium minerals and monazite as primary accessories that have been sheared and metamorphosed together with the rocks into which they were injected, and that the schistose and presumably weak layers thus produced have more frequently than others been the seat of subsequent injections of pegmatitic material that passes to pure quartz. In the cases examined the material of the supposed dikes is characterized, with the single exception of the Dattas rock, by the mineral monazite which, so far as at present known, may be taken as peculiarly characteristic of granitic magmas. The original dikes may therefore be presumed to have been acid porphyries, or basic phases of such porphyries. If, however, this conclusion is correct, all eruptives of whatever nature existing in the series previous to the uplifting and shearing must have suffered a similar change and afforded planes of weak strata favorable to the subsequent injection of pegmatites, or of other types of eruptives. In the overlying series to which the conglomeritic diamond-bearing deposits examined belong, the quartz veins observed show none of these characteristics and appear to be ordinary veins of segregation. The same is also the case with the very numerous and large veins observed along about fifty miles of road over a newer series of graywackes, slates and limestones in the region lying immediately to the west of the gold and diamond section of the Serra do Espinhaço. On the other hand, a number of scattered observations indicate that the veins of the gold-mining districts of the Serra do Espinhaço present characteristics similar to those of the diamond district and difficultly reconcilable with the current hypotheses of a purely segregational origin. In the only one that has been critically examined, that of Passagem near Ouro Preto, Dr. Hussak, as already referred, has found characteristic granitic accessories and contact minerals in a great sulphuret vein, and as the somewhat similar veins of the Pary and Morro Velho mines carry garnets in the one case and microscopic zircons in the other, it may be suspected that they will on close examination, for which material is unfortunately not at hand, give a similar result. Dr. Hussak has also shown in his various papers in the Mineralogical Magazine, on the remarkable association of minerals in the cinnabar-bearing gravels of Tripuhy, that these carry monazite and xenotime, the latter of the same type as in the Diamantina district, along with the curious titano-antimoniates of which one has been traced to a sericitic schist very similar in appearance to that above described, and to a pyritiferous sericitic schist found in place in the immediate vicinity in which rare prismatic fragments of monazite of the Sopa type were detected. Lithomarge with other peculiar clays are, with quartz, characteristic features of the topaz and euclase-bearing veins near Ouro Preto, and lithomarge is a constant accompaniment of the peculiar gold and iron-bearing *jacutinga* veins (?) in the iron ore beds of the same region. Thus the association of argillaceous materials with quartz veins is wide spread and varied in its occurrence, and the observations here recorded are suggestive of the necessity of a careful revision of the current hypothesis regarding the segregational origin of many of these veins.

Both the monazite and the xenotime of the clays and rocks above described and of the concentrated washings of the mines to which they have contributed, present peculiarities of form that distinguish them from the types that have hitherto been found in place in Brazilian, or other, rocks. The monazite crystals are invariably in elongated prisms with only the pinacoid plane developed giving forms that exactly resemble simple prisms of zircon with broken terminations. The extremities are most frequently broken, but occasionally one or two terminal planes are observed as in the accompanying figure kindly drawn by Dr. Hussak. The smallness of the extinction angle (1°–4°) increases the resemblance to zircon, which is so close that only by chemical tests and the measurement of the angles (for which material of sufficient size was fortunately found in the diamond concentrates) could their true character be determined. The xenotimes are invariably elongated prisms with pyramidal terminations in strong contrast with the octahedral type, which is the only one hitherto found in the numerous rocks containing the mineral that have been examined. The crystals when perfect are as transparent and lustrous as zircons, but are quite subject to a milky alteration and are extremely brittle. They rarely sink to the extremely minute size of the generality of the monazite crystals and show a tendency to assume macroscopic proportions. Brown opaque crystals of this prismatic type up to 10 millimeters or more in length, are quite abundant in the concentrates of the mines about the village of Dattas, a few miles to the southward of the localities above described, and there can be no doubt that they come from quartz and kaolin veins like those of São João da Chapada and Sopa. The octahedral type which commonly occurs in the monazite-bearing granites and porphyries, and which was actually found in one of the clays from Sopa, is comparatively rare in the concentrates examined from the Diamantina region, but is abundant and of macroscopic proportions in those from the Lençoes region in Bahia. Perhaps its tendency to alteration noted in the Sopa clay may explain its rarity.



a (100), *b* (010), *x* ($\bar{1}$01), *w* (101).

Since the above was written I am enabled, through the extreme kindness of Profs. Clarke and Hillebrand of the U. S. Geol. Survey, to add the following very minute and painstaking analysis of the peculiar rock from the Serra do Gigante, which, as indicated in the above discussion, is the most promising for giving an idea of the hypothetical original rock type from which the various schists here described may be presumed to be derived. At my request special attention was given to the detection of rare elements of which those of the cerium group and lithia were, from a preliminary examination, presumed to be present in an abundance that failed to be verified. Contrary to expectation, the rock proves to be chloritic rather than sericitic, though, as I am informed, the petrographic examination made in Washington confirmed the opinion formed here that the appearance of the predominant micaceous element is that of a muscovite mica. Contrary to expectation also, the rock proves to be basic rather than acid, and thus the principal difficulty in the way of the attempted affiliation with the Dattas and São João schists of diabasic, or basaltic, aspect is removed. On the assumption, based on the complete absence of recognizable allothigenetic elements, that the original rock was eruptive, no affiliation with any known type of which analyses are at hand can be made.

Analysis of Cyanitic schist, from Serra do Gigante, near Diamantina, Brazil, by W. F. Hillebrand.

	Whole mass.	HCl extract.	H_2SO_4 ext.	Residue insol. in H_2SO_4
SiO_2	38·32	10·78	14·76	(23·56)
TiO_2	4·93	·10	·20	(4·73)
ZrO_2	·09	trace ?	?	(·09) ?
Al_2O_3	28·16	10·42	14·77	(13·39)
Fe_2O_3	2·24	(1·78)	(2·24)	none
FeO	4·02	(3·21)	(4·02	"
$(Ni, Co)O$	·04	?	(·04)	----
MnO	·16	?	(·16)	----
CaO	·32	·34	·32	----
SrO	trace	?	?	----
MgO	12·04	9·34	(12·04)	none
K_2O	1·11	·26	(·26)	·85
Na_2O	·16	(·03)	(·03)	·13
Li_2O	strong trace	strong trace	(strong trace)	faint trace
H_2O, 105°	·55	(·55)	(·55)	----
H_2O, 220°	·45			
H_2O, 310°	·22	5·36	6·80	·66
H_2O, 310°+	6·79			
P_2O_5	·47	·47	(·47)	----
S	trace	----	----	----
F	trace ?	----	----	----
	100·07	42·64	56·66	43·41

No boron, nor rare earths.

Notes to the Foregoing Analyses.

"The bracketed figures are either assumed or follow from direct determinations in one of the other columns.

An hour's treatment with concentrated sulphuric acid is sufficient for extraction of all the soluble constituents. Probably very prolonged action of hydrochloric acid would have had the same effect. The silica from the decomposed silicates separated on rotation in the insoluble form. The lithia belongs to a soluble mineral, for but a faint trace was found in the residue. The P_2O_5 is wholly extracted by dilute nitric acid; it can therefore hardly exist as monazite. Moreover, careful tests failed to show a trace of rare earths. Still the lime is quite insufficient to form apatite with all the P_2O_5.

No formula for the soluble portion can be calculated from the analyses, but according to Professor Clarke it would seem to approach in composition an impure earthy chlorite.

The insoluble residue, after treatment by hydrofluoric and sulphuric acids, contained besides a large amount of unattacked rutile, practically only silica and alumina in the proportions required for cyanite. Assuming that the alkali of the residue belongs to sericite, as indicated by Professor Derby's letter accompanying the specimen, and deducting accordingly for the formula of typical muscovite ($KH_2Al_3Si_3O_{12}$), the following percentages remain after excluding all TiO_2 as rutile: SiO_2 19·62, Al_2O_3 10·24, H_2O ·27. Again assuming that the alumina exists herein as cyanite and deducting Al_2O_3 and SiO_2 to correspond, there remains 13·66 per cent of free silica. This can hardly be opaline silica, for an hour's digestion of the insoluble residue with strong potassium hydroxide solution extracted but a fraction of a per cent of silica."

In view of the apparent disaccord in some points of this analysis with the results above recorded of the physical examination with batêa, heavy liquids and microscope, the latter has been repeated with special care and on a sufficient quantity (20 grams or more) to secure a reliable result. The presence in considerable abundance of free quartz and of rutile was fully confirmed, but no reliable trace of apatite or of zircon could be found. The former if present at all, which is doubted, must be in a proportion too small to account for more than an extremely minute portion of the phosphoric acid and lime, and the latter is certainly absent. The zirconia found in the analysis must be from some other mineral and presumably from the soluble constituents of the rock. A mineral closely resembling zircon, and like it heavier than cyanite, is completely dissolved out of a mixed residue by sulphuric acid, and in the solution very satisfactory tests for phosphoric acid and cerium were obtained, the latter being precipitated as oxalate, and verified by the Florence method in both a borax and salt of phosphorus bead. Isolated grains gave also a very satisfactory microchemical reaction for phosphoric acid and a somewhat doubtful one for cerium, but no definite reaction for the latter could be obtained by the blowpipe method, probably on account of the smallness of the quantity of pure material available or of some disturbing admixture. On the strength of these observations and of the close resemblance in form and optical properties with the mineral from the Sopa clay, the original determination as monazite is maintained. The Sopa mineral is undoubtedly a cerium phosphate and apparently agrees in form with submacroscopic crystals from the diamond concentrates on which the angles of monazite were verified. It appears, however, to carry some titanium and lime, and possibly this peculiar type of monazite may present peculiarities of composition. The facility with which the mineral can be isolated from the Sopa schist gave an opportunity to determine roughly, by washing, its proportion as about 0·01 per cent. It is apparently much less abundant in the Serra do Gigante rock and therefore could hardly be expected to appear in the quantity ordinarily employed in a chemical analysis. It seems probable also that this rock carries some other undetermined phosphate.

Commissão Geographica e Geologica,
S. Paulo, Brazil.

ART. XXXIX.—*Goldschmidtite, a New Mineral;* by WILLIAM H. HOBBS.

THE analyses of Hillebrand and the crystallographical studies of Penfield which were made in connection with the monograph of Cross and Penrose* on the Cripple Creek Mining District have established the fact that the chief telluride ore of the district is the mineral calaverite, containing about three per cent, or less, of silver. The presence of this mineral in the ores had previously been determined by Knight† by chemical analysis. Mr. R. Pearce‡ of Denver had, however, assayed an ore-bearing rock from the Moose Mine, and found it to contain gold, silver, and tellurium in proportions corresponding with sylvanite, so that he believed this mineral to be present. From the complex nature of the material assayed these results can hardly be regarded as conclusive, but to the writer they would seem to indicate at least the probability of the presence of a gold-silver telluride, richer in silver than calaverite, particularly since the output of silver from some of the mines is too large to be fully accounted for by the presence of calaverite alone. Dr. Hillebrand says:

"Notwithstanding that sylvanite has not been identified by positive chemical or crystallographical tests, the evidence of Mr. Pearce as to its presence in some portions of the district at least is entitled to consideration" (l. c., p. 133).

Source of the Material examined.

The material which I have studied was kindly given me for examination by Mr. Gustavus Sessinghaus, a graduate of the Columbia School of Mines, and now a graduate student of the University of Wisconsin. It was obtained from the Gold Dollar Mine in Arequa Gulch, in the extreme southwestern portion of the Cripple Creek Mining District. This mine is located on the northwest quarter of Section 31. (Cf. Plate VII, l. c.) It is near the flank of Grouse Mountain. The material consists of a single small hand specimen, the matrix of which is a breccia in which fragments of granite are conspicuous. Comparison with the gneissose granite of Grouse Mountain shows that the enclosures in the rock have probably been derived from that source. The cementing material of the breccia resembles the phonolite of the region, with which it probably corresponds in composition. The fragments of the breccia are, however, only loosely consolidated, so that the specimen is crossed by numerous irregular cracks, the walls of which are coated with chalcedony.

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*Geology and Mining Industries of the Cripple Creek District, Colorado; by Whitman Cross and R. A. F. Penrose, Jr. 16th Ann. Report, U. S. Geol. Survey, 1894-5, Pt. II, pp. 1-209.

† Proc. Colo. Sci. Soc., Oct. 1, 1894. ‡ Ibid., April 5, 1894.

The crystals of the mineral which is here discussed are firmly attached to the chalcedony, so that great difficulty was experienced in removing them without fracture, particularly as they are possessed of a perfect cleavage. These crystals have a rather long columnar habit with some tendency also to elongated tabular forms with reference to a plane parallel to this axis, and in one or two cases they were observed to have the arborescent forms which have given the name "Schrifterz" to the mineral sylvanite, and have been explained by twinning. The largest individual observed was only about 5^{mm} in length and those which I have succeeded in separating from the chalcedony of the walls would average hardly 2^{mm} in length, with a thickness perhaps a third or a fourth as much. Examination with the lens showed these crystals to be considerably modified and without striation or other distortion, and, except for their minute size, they are admirably suited to measurement. They have a perfect cleavage following the plane of their tabular development. They are seen to be often twins, the plane of twinning following the columnar axis in a direction normal to the cleavage. They are quite brittle and have a hardness of about 2, since they will just scratch the surface of selenite. The amount of material was not sufficient for a satisfactory determination of the specific gravity, but the mineral's composition as recorded below, and the comparison of it with sylvanite and calaverite, make it probable that the specific gravity is very near to 8·6. The luster of the mineral is bright metallic and the color a silver white. The streak is dull, grayish black.

Chemical Composition.

Examined on charcoal before the blowpipe, the mineral readily fuses surrounded by the light bluish green flame which is characteristic of tellurium, leaving on the coal a white coating of tellurium oxide. A yellowish white button of gold and silver results from the fusion, as in the cases of sylvanite and calaverite, though it is much less yellow than the button obtained from the last mentioned mineral. No antimony, sulphur, or selenium could be detected.

A portion of the specimen was broken up and by careful and laborious picking out of the crystals and fragments of crystals about one-tenth of a gram of nearly pure mineral was obtained, which was analyzed and found to contain gold, silver, and tellurium, in the following proportions, the tellurium being estimated by difference:

	Percentage composition.	Ratio.
Au	31·41	·1596
Ag	8 95	·0831
Te	(59·64)	·4771
	100·00	

These proportions correspond almost exactly with the formula Au_2AgTe_6, and show that the mineral is a new species, which I propose to call Goldschmidtite, in honor of my friend, Professor Victor Goldschmidt, of Heidelberg, the inventor of the two-circle goniometer and the author of *Index der Krystallformen* and *Winkeltabellen*.

Below are given in parallel columns the estimated and the theoretical proportions of the constituents of this mineral on the basis of the formula Au_2AgTe_6:

		Calculated.
Te	(59·64)	59·95
Au	31·41	31·44
Ag	8·95	8·61
	100·00	100·00

Relationships with other Tellurides of Gold and Silver.

The mineral sylvanite contains the same elements as Goldschmidtite but in the proportions represented by the formula $AuAgTe_4$.* The mineral calaverite differs in being richer in gold and is not generally credited with a definite formula, because of slight variations noted in the content of silver. The number of analyses of this mineral which have now been made renders it possible, as it seems to me, to arrive at a more definite formula than $(Au,Ag)Te_2$, which assumes an isomorphous relation between gold and silver in the compound that does not exist so far as we know. Comparison of the analyses of calaverite which are given below brings out their striking uniformity with the exception of the silver percentage, and this would seem to indicate that a mineral corresponding to the one having the highest silver percentage (3·52) may form isomorphous mixtures with one that is richer in gold or perhaps entirely free from silver. Since, however, a large proportion of the analyses contain silver in amounts approximating the maximum percentage, it is improbable that isomorphous mixtures occur with tellurides much richer in silver. The formula $Au_9Ag_{\frac{5}{3}}Te_{21}$ seems best to represent the composition of this mineral.

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* Groth, Tabellarische Uebersicht der Mineralien, 4te Auflage, Braunschweig, 1898, p. 28.

Analyses of Calaverite.

	Te	Au	Ag	Total
1. California, Genth[*]	55·89	40·70	3·52	100·11
2· " " [†]	(56·00)	40·92	3·08	100·00
3. Bowlder Co., Colo. Genth[‡]	57·67	40·59	2·24	100·50
4. " " " [§]	57·32	38·75	3·03	99·10
5. Cripple Creek, Colo. Hillebrand[‖]	57·60	39·17	3·23	100·00
6. " " " [¶]	57·40	40·83	1·77	100·00
7. " " " [**]	57·30	41·80	·90	100·00
Calaverite of formula $Au_9Ag\frac{5}{3}Te_{21}$	57·40	39·08	3·52	100·00

Comparison of the minerals calaverite, Goldschmidtite, and sylvanite brings out the fact that Goldschmidtite is, as regards its composition, intermediate between calaverite and sylvanite and almost exactly half way between them. Together the three minerals represent an homologous series quite analogous to that which has been determined for the minerals of the humite group by Penfield and Howe.[††] This will be clear from the following table:

	Te		Au		Ag	
	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.	Ratio.
Calaverite	57·40	·4544	39·08	·1987	3·52	·0327
$Au_9Ag\frac{5}{3}Te_{21}$	(21 =	·4536)	($\frac{27}{3}$ =	·1944)	($\frac{5}{3}$ =	·0363)
Difference	2·55	·0256	7·54	·0388	5·09	·0473
Goldschmidtite	59·95	·4800	31·44	·1600	8·61	·0800
Au_2AgTe_6	(22 =	·4752)	($\frac{22}{3}$ =	·1584)	($\frac{11}{3}$ =	·0799)
Difference	2·20	·0176	6·99	·0336	4·79	·0444
Sylvanite	62·15	·4976	24·45	·1244	13·40	·1244
$AuAgTe_4$	(23 =	·4968)	($\frac{17}{3}$ =	·1235)	($\frac{17}{3}$ =	·1235)

From the above table it is seen that the common difference between consecutive members of the series in ascending order is a gain of Ag_2Te and a loss of $Au\frac{5}{3}$. For purposes of comparison the formulæ of the three minerals should therefore be written:

Calaverite .... $Au\frac{27}{3}Ag\frac{5}{3}Te_{21}$.
Goldschmidtite ...... $Au\frac{22}{3}Ag\frac{11}{3}Te_{22}$.
Sylvanite............ $Au\frac{17}{3}Ag\frac{17}{3}Te_{23}$.

The next member of the series should have the formula:

$$Au\frac{12}{3}Ag\frac{23}{3}Te_{24}$$

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[*] This Journal, xlv, 1868, p. 314.
[†] Ibid.
[‡] Am. Phil. Soc., xiv, 1874, p. 229.
[§] Ibid., xvii, 1877, p. 117.
[‖] 16th Ann. Report U. S. G. S., Pt. II, p. 133.
[¶] Ibid.
[**] Ibid.

Note.—The mineral krennerite is a telluride of gold and silver richer in silver than sylvanite, but the wide and remarkable variations in the proportions of its constituents cause it to be regarded as of very indefinite composition.

[††] On the Chemical Composition of Chondrodite, Humite, and Clinohumite. This Journal, xlvii, 1894, p. 188–206.

which is a close approximation to $\mathrm{Au_1Ag_2Te_3}$. The mineral krennerite contains silver in about this proportion (19·44 per cent), but the proportions of gold and tellurium do not correspond.

Crystallography of Goldschmidtite.

As already stated, the chief difficulty encountered in measuring the crystals has been their minute size and the consequently small amount of light reflected from their faces. A number of the better faces afforded single images of the signal so that in the prism zone, where the faces were largest, consecutive readings from the same angle showed variations of less than a minute of arc, and on the best crystal the four similar angles between prism and pinacoid were respectively:

61° 42′
61 46
61 46½
61 47½

Considerable confidence is therefore placed in the correctness of the constant which was determined from the angles in this zone, while the values of the other constants are correct only within limits of error which are sufficiently indicated by a comparison of observed and calculated values of readings of interfacial angles. Five crystals have been completely measured and particular angles have been measured also upon other crystals.

The symmetry of the mineral is easily determined as monoclinic, and it is probably also clinohedral. The principal zones of the crystal are those of the axes $\dot{c}$ and $\bar{b}$, a single clinodome and a pyramid which was too small to be determined being the only faces not included in these zones. Owing to the frequent absence and the small development when present of the basal pinacoid, the angle β was determined from the mutual inclinations of the positive and negative unit orthodomes and found to be 89° 11′. The axial ratio $a:b:c$ is 1·8562 : 1 : 1·2981. The crystal forms observed number twenty-two, and are as follows:

Zone of $\dot{c}$.— a (100) $i\text{-}\bar{\imath}$; b (010) $i\text{-}\grave{\imath}$; m (110) I; f (210) $i\text{-}\bar{2}$; g (310) $i\text{-}\bar{3}$; t (370) $i\text{-}\frac{\grave{7}}{3}$; l (130) $i\text{-}\grave{3}$.

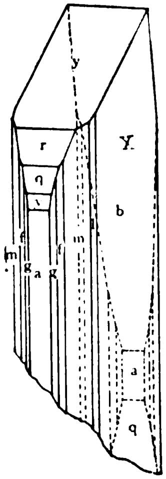
Zone of $\bar{b}$.— y (508) $-\frac{5}{8}\text{-}\bar{\imath}$; s (101) $-1\text{-}\bar{\imath}$; n (201) $-2\text{-}\bar{\imath}$; r (703) $-\frac{7}{3}\text{-}\bar{\imath}$; w (401) $-4\text{-}\bar{\imath}$; q (801) $-8\text{-}\bar{\imath}$; x (10·0·1) $-10\text{-}\bar{\imath}$; v (35·0·1) $-35\text{-}\bar{\imath}$; S ($\bar{1}$01) $1\text{-}\bar{\imath}$; N ($\bar{2}$01) $2\text{-}\bar{\imath}$; W ($\bar{4}$01) $4\text{-}\bar{\imath}$; X ($\bar{1}\bar{0}$·0·1) $10\text{-}\bar{\imath}$; Z ($\bar{1}\bar{4}$·0·1) $14\text{-}\bar{\imath}$; c (001) O.

Zone of $\grave{a}$.—k (032) $\frac{3}{2}\text{-}\grave{\imath}$.

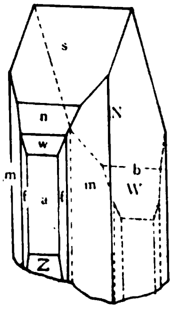
The more important angle readings from which these determinations were made are as follows:

						Obs.	Calc.	Diff.
a	:	*m*	(100)	:	(110)	61° 41′*		
b	:	*m*	(010)	:	(110)	28 18	28° 19′	−1′
a	:	*f*	(100)	:	(210)	42 43	42 52	−9
a	:	*g*	(100)	:	(310)	31 55	31 45	+10
b	:	*l*	(010)	:	(130)	9 57	10 11	−14
b	:	*k*	(010)	:	(032)	26 49	27 18	−29
a	:	*y*	(100)	:	(508)	65 7	65 42	−35
a	:	*s*	(100)	:	(101)	54 57	54 29	+28
a	:	*n*	(100)	:	(201)	34 13	35 17	−64
a	:	*r*	(100)	:	(703)	31 40	31 17	+23
a	:	*w*	(100)	:	(401)	19 10	19 35	−25
a	:	*q*	(100)	:	(801)	10 3	10 6	−3
a	:	*x*	(100)	:	(10·01)	7 44	8 7	−23
a	:	*v*	(100)	:	(35·01)	2 22	2 20	+2
a	:	*c*	(100)	:	(001)	89 25	89 11	+14
b	:	*c*	(010)	:	(001)	89 59	90 0	+1
b	:	*t*	(010)	:	(370)	12 53	13 0	−7
a	:	S	(100)	:	$(\bar{1}01)$	55 35*		
a	:	N	(100)	:	$(\bar{2}01)$	34 58	36 0	−62
a	:	W	(100)	:	$(\bar{4}01)$	19 18	19 46	−28
a	:	X	(100)	:	$(\bar{1}\bar{0}\cdot 01)$	7 48	8 9	−21
a	:	Z	(100)	:	$(\bar{1}\bar{4}\cdot 01)$	5 49	5 44	+5
b	:	*k*	(010)	:	(032)	26 49	27 18	−29

1.



2.



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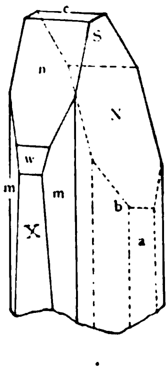


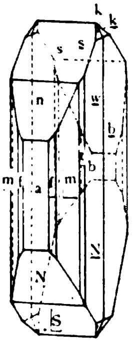
Of the five crystals measured, crystal I (fig. 1) is bounded by the forms *a*, *b*, *m*, *f*, *g*, *l*, *v*, *q*, *r*, *y*, and X. Crystal II (fig. 2) is bounded by *a*, *b*, *m*, *f*, *w*, *n*, *s*, Z, W, and N. Crystal III (fig. 3) exhibits the combination *a*, *b*, *m*, *c*, *w*, *n*, X, N, and S.

Crystal IV (fig. 4) is doubly terminated and represents a simple twin with the twinning plane the orthopinacoid. One of its individuals (the front one in the figure) displays the forms *a*, *b*, *m*, *f*, *t*, *n*, *s*, N, S, and *k*. The other individual differs in having only one positive orthodome (N) and the form *w* in place of *n*. Crystal V (fig. 5) is also a twin crystal, on the front individual of which are developed the forms *a*, *b*, *m*, *c*, *k*, and *s*. The other individual exhibits in addition *n* and lacks the basal pinacoid. A small pyramid lying between *k* and *s* I was unable to determine. All the crystals show a remarkably perfect cleavage following the plane of symmetry.

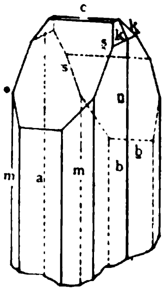
Crystallographical Affinities of Goldschmidtite and Sylvanite.

As might be expected from its chemical relationship to sylvanite, the mineral Goldschmidtite exhibits affinities also in its crystal development. Both minerals have monoclinic symmetry and somewhat similar forms are developed upon them. Ten of the twenty-two forms discovered on Goldschmidtite have representatives on sylvanite. Below are given in parallel columns the crystallographical constants of the two minerals and some of the angle readings between faces of corresponding forms. It will be noted that the differences are greatest in the prism zone, where the largest faces of Goldschmidtite make the error of reading comparatively small. The orientation of sylvanite is that of Schrauf, which is now generally adopted.

4.



5.



The axes $\dot{a}$ and $\dot{c}$ are each about one-seventh longer in Goldschmidtite than in sylvanite. It is to be regretted that satisfactory material is not available for the crystallographical study of calaverite. That studied by Penfield[*] was so poor that he was unable to determine the crystallographical constants. He thinks the mineral is probably triclinic, with its angles somewhat similar to those of sylvanite. It lacks the pinacoidal cleavage of that mineral but is observed in twins according to the face of (101). When suitable material is available for study it will be interesting to see whether relations between the lengths of the crystallographical axes and the proportions of its constituent elements, can be discovered, as has been done in the case of the minerals of the humite group.

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[*] l. c., p. 135.

Goldschmidtite	Sylvanite
Au_2AgTe_6	$AuAgTe_4$.
Monoclinic	Monoclinic
$\beta = 89° 11'$	$\beta = 89° 35'$
$a : b : c$	$a : b : c$
1·8562 : 1 : 1·2981	1·6339 : 1 : 1·1265
Perfect cleavage (010)	Perfect cleavage (010)
Common twinning plane (100)	Common twinning plane (101)
Columnar axis, c	Columnar axis parallel to (101)

	Angles.	Angles.	Diff.
$a : m$	61° 41′	58° 32′	+3° 9′
$b : m$	28 18	31 28	−3 10
$f : a$	42 42	39 15	+3 27
$s : a$	54 57	54 57	
S : a	55 35	54 52	+ 43
$n : a$	34 13	35 48	−1 35
$n : s$	20 43	19 9	+1 34
a : N	34 58	35 16	− 18
$c : a$	89 25	89 35	− 10
S : N	20 37	19 36	+1 1

Conclusions.

1. Goldschmidtite is a new mineral species of composition represented by the formula Au_2AgTe_6.

2. It occupies an intermediate position exactly half way between calaverite and sylvanite.

3. Calaverite, Goldschmidtite, and sylvanite form together an homologous series, analogous to that of the minerals in the humite group, the common difference being the addition of Ag_2Te and the subtraction of Au$\frac{5}{3}$ in passing from any one of the series to the next above it.

4. Goldschmidtite has monoclinic symmetry with β 89° 11′, and $a : b : c$, 1·8562 : 1 : 1·2981. It exhibits no less than twenty-two crystal forms, most of which are in the zones of $\acute{c}$ and $\bar{b}$.

5. Crystallographically as well as chemically Goldschmidtite shows affinities with sylvanite, ten forms being common to the two minerals, though they are referred to axial unities of which $\grave{a}$ and $\acute{c}$ are each about one-seventh longer in Goldschmidtite than in sylvanite.

University of Wisconsin.

ART. XL.—*On a Hydromica from New Jersey;* by F. W. CLARKE and N. H. DARTON.

WHILE studying the Jura-trias formation in New Jersey, one of us (Darton) found in an old "trap" quarry at Rocky Hill a hydromica, which occurred under such novel conditions that it appeared to be worthy of investigation. It is found in veins of calcite, mainly as a thin coating, and adjacent to the diabase of the vein walls. The latter consist of more or less decomposed rock, of which the principal product is a soft, dark-green chloritic material. In portions of the vein the mica extends down the cleavage planes into the masses of calcite. A considerable amount of the calcite was thrown out during the quarrying operations, but only a portion of it is covered with the mica. This portion presents the appearance of having been coated with bronze paint.

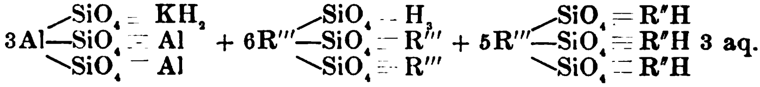
The mica occurs in minute flakes thinly matted together. Its color is golden bronze, although some portions are slightly greenish. The mineral is soft, and thinly foliated. Under the microscope it exhibits no definite crystalline form; and its optical properties, although not distinctive, suggest biotite. It appears to be biaxial, but with a very small axial angle, and it is pleochroic. When heated, it does not exfoliate. It fuses before the blowpipe, at a moderately high temperature, to a dark colored bead. The specific gravity was not determined. It is readily decomposable by hydrochloric acid. The analysis, by Mr. George Steiger, of material not free from calcite, is subjoined. In the second column of figures the *reduced* analysis is given, titanic oxide and calcite being thrown out, soda recalculated to terms of potash, and the whole adjusted to 100 per cent.

	Found.	Reduced.	Ratios.
SiO_2	32·72	40·24	·671
TiO_2	·24	....	....
Al_2O_3	8·41	10·34	·101
Fe_2O_3	19·99	24·57	·154
FeO	4·24	5·21	·072
CaO	10·30	....	....
MgO	5·51	6·78	·166
K_2O	·85	2·20	·024
Na_2O	·63	....	....
CO_2	8·21	....	....
H_2O at 100°	2·47	3·03	·168
H_2O above 100°	6·22	7·63	·424
	99·79	100·00	

This gives, as an orthosilicate, the formula

$$(KH)_{68}(MgFe)_{24}(AlFe)_{51}(SiO_4)_{67}.\quad 28H_2O.$$

It is evident, from these data, that the mica is one which has been largely, but not wholly, altered to a vermiculite; the latter term indicating a mica in which potassium has been replaced by hydrogen, and which has taken up water of crystallization. So far as the analysis goes, the condition of the water is uncertain; for it was determined in two fractions only, at and above 100°, whereas more fractions are needed for accurate diagnosis. Some crystalline water may be retained far above 100°, so that the loss above that temperature includes part of this fraction plus all the water of constitution. Apart from this uncertainty the ratios reduce easily in terms of the mica theory to the following molecular mixture:



$$3\mathrm{Al}\begin{array}{l}\diagup SiO_4 = KH_2\\ -SiO_4 \equiv Al\\ \diagdown SiO_4 - Al\end{array} + 6R'''\begin{array}{l}\diagup SiO_4 \equiv H_3\\ -SiO_4 \equiv R'''\\ \diagdown SiO_4 \equiv R'''\end{array} + 5R'''\begin{array}{l}\diagup SiO_4 = R''H\\ -SiO_4 = R''H\\ \diagdown SiO_4 = R''H\end{array}\ 3\ aq.$$

Calculating with the atomic ratios Al : Fe''' : : 2 : 3, and Fe'' : Mg : : 3 : 7, we have the following comparison between analysis and theory:

	Reduced.		Calculated.
SiO_2	40·24		40·55
Al_2O_3	10·34		10·51
Fe_2O_3	24·57		24·71
FeO	5·21		5·21
MgO	6·78		6·75
K_2O	2·20		2·27
H_2O, 100°	3·03	Crystalline	4·34
H_2O above 100°	7·63	Constitutional	5·66
	100·00		100·00

In short, the mica consists of muscovitic and phlogopitic molecules in the ratio of 9 : 5.

$$9R'''_3(SiO_4)_3R'_3,$$
$$5R'''(SiO_4)_3R''_3H_3,\ 3\ aq.$$

The mineral is evidently an unusual mica, differing widely from any other hitherto described. Its very high proportion of ferric oxide is its chief characteristic, and suggests a ferric muscovite as one of the antecedent, unaltered molecules. Such a muscovite is theoretically conceivable, but is not actually known.

Laboratory U. S. Geological Survey, Feb. 18, 1899.

ART. XLI.—*Powellite Crystals from Michigan;* by CHARLES PALACHE.

POWELLITE was first described by Melville* from a specimen from the "Seven Devils" Mountains, Idaho, where it occurred associated with copper ores and garnet. This material was well crystallized and Melville was able to establish its tetragonal character and the forms *c*(001), *p*(111), and *e*(101). The isomorphism with the scheelite group suggested by the close agreement between the axial ratio and angles of powellite and scheelite was not fully shown, though the author says: "Small rudimentary planes appear on some crystals at the lower portion of the combination edges (111) (101), thus suggesting hemihedrism as in scheelite. Indeed the curved surface which often replaces these edges, giving the appearance of fused edges, adds greatly to the evidence in favor of this supposition."

A second occurrence of powellite, in the South Hecla Copper Mine, Houghton County, Michigan, was described by Koenig and Hubbard.† Their material was poorly crystallized and added nothing to our crystallographic knowledge of the mineral. It differed from the Idaho mineral in its paragenesis, occurring with native copper and epidote, and in its composition, having only about 1½ per cent of its molybdic acid replaced by tungstic acid, as against about 10 per cent in the first occurrence.

Powellite continues to be found at the Michigan locality, though in small quantities and for the most part in massive form. Through the kindness of Mr. John T. Reader, of Calumet, through Dr. L. L. Hubbard, two particularly fine crystals came into the writer's hands and their description follows.

Both crystals are removed from the matrix upon which they grew. They are perfectly free from impurity of any sort and the specific gravity of the larger one could be determined with accuracy by weighing on the hydrostatic balance. Two determinations gave 4·358 and 4·353.

The crystals are pale bluish green in color, translucent, with subadamantine luster on the crystal faces and a greasy luster on fracture surfaces.

The larger of the two crystals is a centimeter in height and has one end complete, but the faces are somewhat uneven; the smaller one is half a centimeter in height and diameter and has both ends developed though neither is quite complete. The quality of its faces is sufficiently good to insure accurate measurements.

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* This Journal, vol. xli, 1891, p. 138.

† This Journal, vol. xlvi, 1893, p. 356.

The measurements were made on a two-circle goniometer (Goldschmidt model) and the observed angles therefore appear in the form of the angular coördinates, ϕ and ρ, as used in the Winkeltabelle of Goldschmidt.

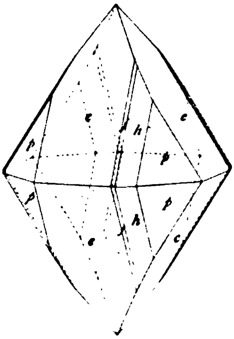
The forms observed were:

p(111) *e*(101) *h*(133) *j*(3·11·11) *k*(155) *l*(1·11·11).

and the following table shows the observed and calculated angles.

Letter.	Symbol.		Observed angle.		Calculated angle.		No. of times observed.
	Miller.	Gold't.	ϕ	ρ	ϕ	ρ	
e	011	01	00° 00′	57° 04$\frac{2}{3}$′	00° 00′	57° 00′	3
p	111	1	44 59	65 24	45 00	65 24	2
h	133	$\frac{1}{3}1$	18 28	58 25$\frac{1}{2}$	18 26	58 26	2
j	3·11·11	$\frac{3}{11}1$	15 08	58 00	15 15	58 00	3
k	155	$\frac{1}{5}1$	11 19	57 38	11 18	57 35	1
l	1·11·11	$\frac{1}{11}1$	5 11	57 08	5 11	57 11	1

As shown by the accompanying figure, the pyramidal hemihedrism is strongly emphasized by the faces of *h*(133) and *j*(3·11·11), the first especially being broad and of perfect quality. The other two hemihedral forms, *k*(155) and (1·11·11) were very narrow faces in the zone, and as they were each observed but once they must be considered as doubtful and were therefore not introduced into the figure. There is a tendency for these planes to form a striated or curved surface between the forms *p* and *e* such as Melville observed, but there were two zones on the crystal in which the faces were sharply enough bounded to give good measurements.



The measurements lead to the same axial ratio as those made by Melville and the isomorphism of the species with the scheelite group is thoroughly established.

With the crystals of powellite sent by Dr. Hubbard was another specimen of the mineral of quite a different appearance. It consists of a rounded mass of powellite about two centimeters in diameter, upon which are a few small fragments of rocky matrix, minute crystals of bright green epidote and two or three shreds of native copper. On the broken surfaces the powellite shows an imperfect cleavage, seemingly parallel to *e*(101). The central part of the specimen is of the same bluish-green color as the crystals, but the surface layer to the depth of about three millimeters appears quite black and opaque in reflected light and when examined in thin splinters is seen to be colored a deep prussian blue. The boundary between the two colors is not sharp but the darker portion shades off rapidly into the lighter part.

The dark-colored material is crystallized in a number of small individuals, all in parallel position and showing approximately the same forms as the crystals before described but with greater proportional development of the forms *e* and *h*.

An attempt was made to separate some of the darker material for chemical examination, it being assumed that the lighter colored part did not differ from the similar material analyzed by Koenig and Hubbard; but it proved impossible to obtain a sufficient amount for any satisfactory tests. A small amount (·051 gram) was however picked out in which there was a very slight admixture of light-colored substance and a few minute grains of epidote, and its specific gravity was determined to be 4·214. This determination is not wholly reliable on account of the impurities and the small amount of material, and it is probably too low; but it seems to the writer fairly certain that the specific gravity of the dark material is less than that of the light (4·355). The specific gravity of the pure calcium molybdate has been calculated to be 4·267 (Melville), a value which is rapidly raised by even small quantities of the tungstate. It seems probable, in view of these facts, that the dark blue material represents an occurrence of almost pure calcium molybdate. It is much to be hoped that more material will be found which will permit the chemical proof of the existence of this end member of the scheelite-powellite series.

Mineralogical Laboratory,
Harvard University, February, 1899.

ART. XLII.—*The Volatilization of the Iron Chlorides in Analysis, and the Separation of the Oxides of Iron and Aluminum;* by F. A. GOOCH and FRANKE STUART HAVENS.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXI.]

IT is well known that metallic iron is easily acted upon by an excess of chlorine at moderately elevated temperatures with the formation of ferric chloride, and that the product of the action of hydrochloric acid gas upon the metal is ferrous chloride. Out of contact with air, or moisture, both chlorides may be volatilized at appropriate temperatures—the ferric chloride below 200° C.; the ferrous chloride at a bright red heat. If water vapor, or oxygen, or air be present during the heating, both chlorides are partially decomposed with the formation of non-volatile residues, ferric oxide or ferric oxychloride.

Analytical processes involving the volatilization of iron at temperatures more or less elevated, in an atmosphere of chlorine or hydrochloric acid, have been the object of considerable attention. Thus, Fresenius,* Drown and Shimer,† and Watts,‡ have heated crude iron in chlorine to remove the metal and leave the non-volatile constituents; and Sainte-Claire Deville§ has employed hydrochloric acid to volatilize iron from mixtures of that metal with alumina (obtained by heating the mixed oxides of iron and aluminum in hydrogen according to Rivot),‖ exposing the mixture, contained in a porcelain boat and placed within a porcelain tube, to the bright red heat of a charcoal furnace—an operation which was bettered by Cooke's¶ use of a tube of platinum instead of the porcelain tube and a gas blowpipe in place of the charcoal furnace. Sainte-Claire Deville** showed, further, that ferric oxide may be converted to ferric chloride and volatilized at the heat of the charcoal furnace if the current of hydrochloric acid is sufficiently rapid; but the curious effect was observed that in a sufficiently limited current of the acid no chloride whatever was volatilized, while the amorphous oxide was converted to the highly crystalline oxide of the same composition—a phenomenon which gave rise to a theory of the natural formation of specular iron in volcanic regions.

Quite recently, Moyer†† has made record of an unsuccessful attempt (in the course of experimentation upon the volatility of certain chlorides at comparatively low temperatures) to convert ferric oxide completely to ferric chloride by the action of gaseous hydrochloric acid at about 200° C. At this temperature the greater part of the iron sublimed, but a residue remained, which, volatilizing neither on long heating at 200° nor upon considerable elevation of the temperature, proved upon examination to be ferrous chloride. In the experiments to be described we have acted with gaseous hydrochloric acid upon ferric oxide made by igniting the nitrate prepared from pure iron deposited electrolytically by high currents passing between electrodes of platinum in a strong solution of ammonio-ferrous sulphate. The oxide, contained in a porcelain boat, was heated within a roomy glass tube over a small combustion furnace. The hydrochloric acid (generated by dropping sulphuric acid into a mixture of strong hydrochloric acid and salt, and dried by calcium chloride) entered one end of the tube and passed out at the other through a water trap. In early experiments a high-reading thermometer was inserted through the stopper in the exit end of the tube so that its bulb was above and immediately adjacent to the boat carrying the oxide. In this way the actual temperatures of the vapors about the boat were fixed with considerable accuracy; later, after a little experience in gauging the effect of the burners, it was found that the temperatures could be regulated very closely without actually depending upon the thermometer. We found, as did Moyer, that ferric oxide, submitted to the action of dry hydrochloric acid gas, volatilizes partially as ferric chloride at low temperatures—180° to 200° C.—leaving ultimately a crystalline residue which does not change visibly when heated for an hour or two at 200°, or even at 500°, in the pure dry acid. According to our experience, this residue is generally slightly reddish or salmon-colored; but sometimes, especially after a second heating, the boat having been withdrawn from the tube or exposed to the atmosphere (and so to moisture), the residue is white. When it is white it dissolves in water, yields the characteristic reaction for a ferrous salt with potassium ferricyanide, gives no reaction with potassium sulphocyanide, and upon treatment in weighed amount with potassium permanganate destroys the amount of that reagent theoretically required for its oxidation upon the supposition that it is ferrous chloride. The slightly colored residue when treated with water yields a solution showing the reaction of a ferrous salt only, but when treated with hydrochloric acid and then tested shows the presence of a trace of iron in the ferric condition. Doubtless the coloration of the residue is due to an included trace of ferric oxide or oxychloride, which after exposure of the containing crystals to slight atmospheric action, is more easily reached in the second heating by the gaseous acid. The amount of residue is somewhat variable, but approximates under the conditions of our work to from five to ten per cent of the oxide taken: thus, in one typical experiment 0·1 grm. of ferric oxide left a residue which (withdrawn after cooling) weighed 0·0115 grm.

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* Zeitschr. für Anal. Chem., iv, 72.

† Jour. Inst. Min. Eng., viii, 513.

‡ Chem. News, xlv, 279.

§ Ann. de Chim. et de Phys. [3], xxxviii, 23.

‖ Ann. de Chim et de Phys. [3], xxx, 188.

¶ This Journal [2], xlii, 78.

** Compt. Rend., lii, 1264.

†† Jour. Amer. Chem. Soc., xviii, 1029.

The greater portion of the ferric oxide volatilizes when submitted to the action of the gaseous acid at 200° quickly and abundantly in the form of the greenish vapor of ferric chloride, and if the operation is interrupted at this stage the residue which remains is nearly black, insoluble in water, slightly soluble in cold hydrochloric acid, and readily soluble in hot hydrochloric acid with the formation of ferric chloride. It is probably something analogous to the oxychloride which Rousseau* identifies as the product of the action of water upon ferric chloride at 275° to 300°. This dark residue yields to the action of the hydrochloric acid at 180° to 200° only slowly, but ultimately only the residue which is essentially ferrous chloride remains; thereafter little volatilization occurs within the range of temperature of our experimentation—200° to 500°.

It is obvious that a reduction of iron in the ferric condition to iron in the ferrous condition takes place under the conditions of our work, and it is difficult to see how this can occur otherwise than by the direct dissociation of ferric chloride under the low partial pressure conditioned by the brisk current of hydrochloric acid gas. The temperature of formation, 180° to 200°, is far below that at which such dissociation is supposed to begin. Thus, Gruenewald and Meyer† found, after cooling, no evidence of the dissociation of ferric chloride which had been heated in the Victor Meyer vapor-density apparatus to 448° in contact or partial mixture with nitrogen; but ten per cent of the residue obtained by heating to 518° was in the ferrous condition. Friedel and Crafts,‡ however, did see crystals of ferrous chloride at 440° on the walls of a Dumas container filled with the vapor of ferric chloride and nitrogen, the former exerting a partial pressure of 0·75; while ferric chloride volatilized into an atmosphere of chlorine without evidence of dissociation. It seems rather surprising, therefore, to find so large a percentage of dissociation as that shown in our experiments at a temperature so low—180° to 200°. Curiously, too, we find, on repeating the experiment of heating ferric oxide in gaseous hydrochloric acid, that if the temperature of the oxide is 450° to 500° when the brisk current of acid begins to act, the whole mass of oxide is converted and volatilizes without residue. It is hardly to be supposed that the degree of dissociation at 450° to 500° can be less than that at 180° to 200°, and a test of the sublimate, after cooling, shows that it contains a ferrous salt. Plainly, ferrous chloride (formed by dissociation) has volatilized, and inasmuch as the ferrous chloride constituting the residue formed at 180° to 200° does not volatilize in the hydrochloric acid even at 500°, it is plain that the volatility of the former is not determined by the presence of the latter. Apparently, the cause of the completeness of volatilization must be sought in its rapidity; and this is not an unreasonable hypothesis, if one considers that an action sufficiently rapid to keep above the boat an atmosphere of ferric chloride and its products of partial dissociation, might naturally provide the very condition which would be effective in counteracting the tendency of the residue to dissociate before it volatilizes. If this hypothesis is correct, it is plain that the introduction of chlorine gas, the active product of dissociation, into the atmosphere of hydrochloric acid ought to bring about the volatilization of the residue of ferrous chloride, formed at 180° to 200°, which refuses to volatilize in the acid alone. As a matter of fact, we find by experiment that if a little manganese dioxide is added to the contents of the generator, so that the hydrochloric acid may carry with it a little chlorine, every trace of ferric oxide is volatilized from the boat at 180° to 200°; and the residue of ferrous chloride found at 180° to 200° when the hydrochloric acid is used alone is likewise volatilized at the same temperature, when the admixture of chlorine is made.

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* Compt. Rend., cxvi, 118.

† Ber. d. d. Chem. Gesell., xxi, 687.

‡ Compt. Rend., cvii, 301.

These facts, that ferric oxide is completely volatile in hydrochloric acid gas applied at once at a temperature of 450° to 500° C., and at 180° to 200° if the acid carries a little chlorine, open the way to many analytical separations of iron from substances not volatile under these conditions. In the experiments of the following table we have applied these methods to the separation of intermixed iron and aluminum oxides. The ferric oxide employed was made, as before, by ignition of the nitrate prepared from iron deposited electrolytically by a strong current passing between platinum electrodes in a solution of ammonio-ferrous sulphate.* The aluminum oxide was made by igniting to a constant weight the carefully washed hydroxide precipitated by ammonia from a pure hydrous chloride thrown down from the solution of a commercially pure chloride by hydrochloric acid.† The hydrochloric acid gas was made by dropping sulphuric acid into strong hydrochloric acid mixed with salt, and a little manganese dioxide was added when the mixture with chlorine was desired. The experimental details are given in the table.

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* The use of an anode of commercially pure iron wire naturally facilitates the operation, but in our experience the deposit thus obtained is likely to carry traces of impurity. In an attempt, too, to prepare pure ferric oxide from the oxalate thrown down out of ferrous sulphate with all precautions, the material obtained still held traces of silica, and possibly alumina, amounting to 0·0004 grm. in 0·1 grm. of the oxide.

† This Journal, II, 346.

Fe_2O_3 taken. grm.	Al_2O_3 taken. grm.	Al_2O_3 found. grm.	Error. grm.	Time. hours.	Temperature. C°.	Atmosphere.
0·1000	....	....	0·0000	½	450–500	HCl.
0·2000	....	....	0·0000	1	"	"
0·1020	0·1015	0·1015	0·0000	½	"	"
0·2145	0·1006	0·1008	+0·0002	¾	"	"
0·1000	....	....	0·0000	¾	180–200°	$HCl+Cl_2$.
0·1000	0·1032	0·1032	0·0000	¾	"	"
0·1072	0·1013	0·1015	+0·0002	1	"	"
0·2045	0·1032	0·1033	+0·0001	1¼	"	"
0·1050	0·1023	0·1019	−0·0004	½	450–500	"
0·2008	0·1007	0·1006	−0·0001	¾	"	"
....	0·1087	0·1087	0·0000	1	"	"

The residual alumina tested in several experiments by fusion with sodium carbonate, solution in hydrochloric acid, and addition of potassium sulphocyanide gave no indication of the presence of iron.

The separation of the iron is obviously complete at 450° to 500° when the mixed oxides are submitted at once to the action of hydrochloric acid gas, or at 180° to 200° when chlorine is mixed with the hydrochloric acid. Plainly, the extremely high temperatures employed by Deville are unnecessary if the mixed oxides are submitted at once to the action of hydrochloric acid at 450° to 500° without previous gentle heating in the acid atmosphere. We prefer, however, to use the mixture of chlorine and hydrochloric acid, not only because the temperature of the reaction is lower, but because it needs no regulation, while the danger of error arising from the liability of ferric chloride to dissociate, or from deficiency of oxidation in the oxide treated, or from mechanical loss due to too rapid volatilization, is avoided.

ART. XLIII.—*Descriptions of imperfectly known and new Actinians, with critical notes on other species*, V; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College*, No. LXII.

Family BUNODACTIDÆ. (Continued from p. 218.)

Bunodactis inornata Verrill. Figure 39.

Actinia inornata Stimpson, 1855.
Bunodes inornata Verrill, Proc. Essex Inst. Salem, Mass., vol. vi, p. 61, [27], 1869, pl. i, fig. 5.

THE type of this species is still preserved, though it has at some former period been partly dried, and is, therefore, much contracted, in a hemispherical shape. The tentacles are wholly retracted. The upper part of the wall is closely covered with rather large concave suckers, but they rather suddenly diminish in size and become confused with the deep, vermiculate, wrinkles on the lower half of the column, though some persist to near the base.

In section, there are 24 pairs of larger complete mesenteries, including two pairs of directives. Alternating regularly with these there are 24 pairs of smaller mesenteries, most of which are incomplete, but are well developed, with a small but prominent muscular pennon near the distal end, occupying a quarter or less of the breadth. The larger mesenteries have strong median muscular pennons, occupying about a third of their breadth. All, or nearly all, the septa bear large gonads. The tentacles, in transverse sections, show a stellate muscular layer, due to the strong radial supports.

The sphincter muscle is large, clearly defined, nearly circular in section.

Hong Kong, at low water mark, in gravel.—Dr. Wm. Stimpson.

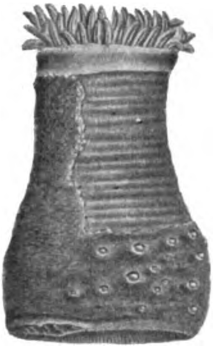
Some Actinians that incubate their eggs externally.

The next four species, described below, are remarkable for the habit of carrying their relatively large eggs attached to the body in special pits, where they are retained until hatched and provided with tentacles. In these cases the egg develops directly into an actinula. This habit was described by me in 1869 as occurring in two of these species, but it has not attracted the attention of others to any great extent. I am now able to add two other species, of large size, having the same habit in a still more striking degree. They belong to the *Bunodactidæ*, but differ considerably in generic characters.

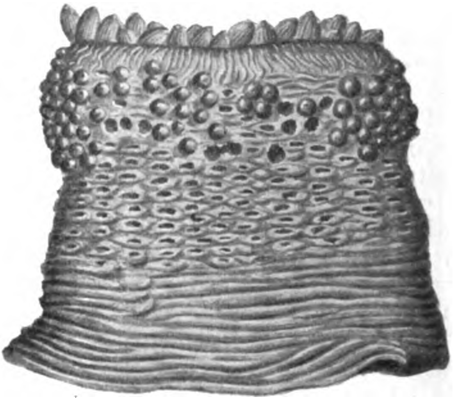
***Pseudophellia*, gen. nov. Type, *P. arctica* Ver.**

Column much elongated, covered with an adherent cuticle, much as in *Phellia*, except near the summit. When the cuticle is removed the surface is finely papillose and wrinkled, in alcohol. Below the middle there are several transverse rows of large pits for carrying eggs. These are deeply excavated in the wall by a thinning of the mesoglœa. Capitulum smooth Wall thick and firm. Sphincter muscle well developed, circumscribed. Mesenteries form about 24 perfect pairs with a few imperfect ones. Two siphonoglyphs and two pairs of directives in the type. Tentacles tapered, in two or more rows.

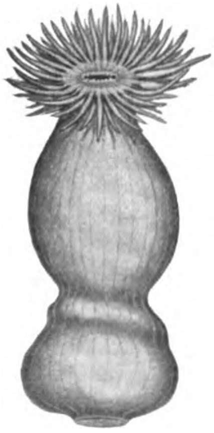
34.



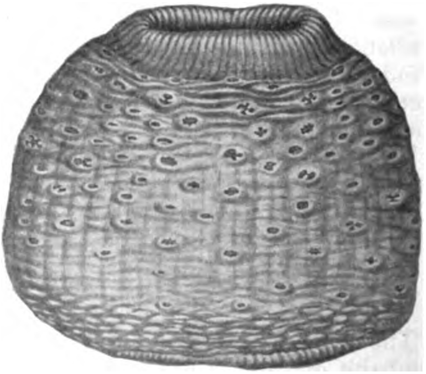
35.



33.



36.



Pseudophellia arctica **Ver. Figure 34 (type).**

Phellia arctica Verrill, Proc. Essex Inst., vol. v, p. 328 [14], 1868; Trans. Conn. Acad., i, p 490, 1869 (*not* of Danielssen*).

The type of this species is still preserved. The original description is pretty complete as to the external appearance, but a typographical error occurred, in the measurement of the eggs. They are ·05 of an inch in diameter (not ·5). When I originally described them I did not feel certain that they were not parasitic structures, but subsequent discoveries have removed this doubt. The mouth has two strong siphonoglyphs and about 18 folds on each side. The stomodæum is strongly plicated. There are about 24 nearly equal pairs of perfect mesenteries, with a few small ones of the fourth cycle. The longitudinal muscles are rather thick and strong on the perfect mesenteries.

The tentacles are rather large and moderately long; they are only partly retracted in the type, but the sphincter muscle is well developed, so that they are probably capable of complete retraction and concealment. In section the sphincter muscle has an ovate outline. The wall is rather thick and firm with a thick mesoglœa, except in the capitulum, which is smooth externally and forms a distinct submarginal fold and small fosse. Circular muscular layer of the wall is well developed. The cuticular layer is thick and soft, and often nearly or quite conceals the eggs when enclosed in the pits, which are largely excavated in the mesoglœa.

Epiactis prolifera Ver. Figure 25.

Trans. Conn. Acad. i, p. 492, 1869.
Epiactis fertilis Andres, op cit., p. 363, 1884.†

The figures now given are from one of the original types.

The largest specimens seen have about 96 tapered tentacles; they can be entirely retracted and concealed.

The wall, in section, is moderately thick and firm, with the different layers very distinct; the ectoderm is rather thick and close; muscular layer well defined and continuous. The sphincter muscle is large, clearly circumscribed, ovate in section, essentially endodermal, but not so much detached from the wall as usual in *Bunodactidæ*. There is a distinct collar and fosse, in contraction. The mesenteries are regularly hexamerous, in four cycles, with some small ones of the fifth; 12 or more pairs are perfect and fertile. Their longitudinal muscles are not very thick, but cover most of their breadth.

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* The *Phellia arctica* Dan. (Actinida, p. 54, 1870) is a true *Phellia* and may be called *P. Danielsseni*, to avoid confusion with our species.

† Andres changed the specific name on account of its prior use for *Gonactinia prolifera* Sars, but that belongs not only to a different genus, but to a widely different family, so that the change of name was not necessary.

The stomodæum is strongly plicated and has two large siphonoglyphs. The ovaries, in some cases, contain large eggs, like those carried on the outside. The egg-pits are not so deep as in the preceding three species and at first they are confined to the ectoderm, but as the embryos develop the pits become larger and deeper, partly by a slight invection of the wall and partly by a thinning of the ectoderm and mesoglœa so that at length they may be as deep as half the thickness of the wall, but they never become like the deep pits of the preceding two genera. No acontia could be found.

This genus resembles, in some respects, the *Paractidæ*, but it seems to belong to the *Bunodactidæ*, on account of the sharply circumscribed sphincter muscle, although the latter is not so much separated from the inner layers of the wall as usual in that family.

Epigonactis, gen. nov.

Large stout Bunodactidæ, with numerous large egg-pits on the upper half of the column, arranged in more or less regular rows and often crowded on the upper part, below the collar. These pits, when fully formed, are deeply excavated in the thick mesoglœa and when containing eggs some of the latter may be nearly or quite covered and concealed by the tissues growing around them. In contraction there is a well-developed fold or collar covered with numerous longitudinal grooves, but without verrucæ; fosse smooth. Tentacles numerous, large, rather long, sulcated in contraction. Sphincter muscle large, circumscribed. Perfect mesenteries numerous and fertile. Eggs large. Wall firm and thick, in sections the layers are very distinct; the circular muscular layer shows, in alcohol, as a well-defined, continuous, brownish yellow layer; mesoglœa thick.

Epigonactis fecunda, sp. nov. Figure 35.

Body nearly cylindrical, about as high as broad in contraction; base muscular and strongly adherent, not much wider than the column, or even narrower in one example in alcohol. Tentacles, in the smaller specimen, 72, stout, blunt, some of them rather long, others contracted so that they are only little longer than thick; they are retracted in most cases so that their tips project but little beyond the marginal collar but are not infolded; some of them appear to be perforated at tip, and most are sulcated by contraction. They are arranged in two or three marginal rows. Collar large and prominent, much thickened, but without marginal tubercles; fosse deep, with a nearly smooth surface. Outside of collar and upper parts of column below it are covered with intricate wrinkles and irregular vermiculate elevations, which surround and enclose numerous deep round pits, mostly closely crowded together. In most of the pits there is a large spherical egg, about 2^{mm} in diameter; most of these project beyond the pits, but some are entirely concealed in the thickened integument.

The egg-bearing pits are most numerous within 12 to 15^{mm} of the collar margin, but some occur lower down. They form a conspicuous zone all around the body, in which the eggs are so crowded as to be in contact in the alcoholic specimens. They adhere firmly. Lower down on the column there are sucker-like pits in vertical rows, decreasing in size downward and mostly disappearing near the middle. They are obscured by the wrinkled surface, but become very evident where the soft wrinkled ectoderm is rubbed off.

In vertical section the wall is moderately thick and very firm both in base and column, plicated by wrinkles; the layers are easily visible with the naked eye, both in base and column; the circular muscular layer shows as a continuous yellow line. The mesoglœa is variable in thickness, being thickened near the base and in the basal disk, but especially so at and below the collar, where the egg-pits occur; in this region it is very much thickened around and between the pits, but is very thin under them, so that it is very irregular and much lobulated; above the collar it is thin. The sphincter muscle is large, round or ovate in section, circumscribed and pedicellate. The mesenteries form about 36 pairs, of which 24 or more are perfect, but they are irregularly developed in the different sextants. In one case six fully developed and nearly equal pairs occur on one side of a pair of directives, while on the other side those of the fourth and fifth cycles are much smaller than the rest. The perfect pairs and most of the others bear large and broad longitudinal muscles, which are thick and strongly plicated. All or nearly all the mesenteries bear large gonads, which are so densely crowded together, in the specimen dissected, that it is not possible to separate them, or place them accurately. They contain numerous large ova similar in size and appearance to those on the exterior of the body. Color not recorded.

Height, in alcohol, about 2·25 inches (56^{mm}); diameter 2·5 inches (62^{mm}).

East of Banquereau, off Nova Scotia, 150 fathoms, Sch. "Polar Wave," lot 37, 1878, 1 specimen; off Nova Scotia, 200 fathoms, Capt. John Rowe, lot 35, 1 specimen.

Epigonactis regularis, sp. nov. **Figure 36.**

Body, as contracted in alcohol, nearly hemispherical, with the base as wide as any part. Disk and tentacles concealed. Wall firm and elastic, covered with a yellowish brown ectoderm; not much wrinkled, except near base and on collar. The collar is strong and sulcated, and also finely wrinkled transversely, giving the surface an areolated appearance. Near the base the wrinkles are transverse and wavy. On the upper half of the column there are vertical rows of large egg-pits, some of them circular and cup-shaped, others oval or egg-shaped; some of them are bordered by several small convergent lobes, others with folds, while some are widely open. They carry no eggs in the type, but are evidently used for that purpose. The wall is thickened at the collar, but thin above it; lower down it is of moderate thickness but firm; the three layers are very definite and easily visible to the naked eye, in sections, without staining; the sphincter is large, elliptical in section, well circumscribed. The circular muscle layer is continuous and well-defined.

Tentacles about 90, stout, sulcated, rather obtuse, of moderate length, arranged in three or four crowded rows; mouth large, with two siphonoglyphs, bordered by large lobes.

Mesenteries form about 44 pairs, most of which are perfect and bear gonads. In a section, near the lower part of the stomodæum, 36 perfect pairs were counted, and most of the remaining eight, which were nearly as wide, may be attached lower down. Those next to the two pairs of directives, on each side, were the least developed. Owing to the equality in the size of the mesenteries no definite hexamerous arrangement could be made out. The longitudinal muscles are very broad, covering nearly the whole breadth of the mesenteries, thick and pleated; those of the directives are less thick, but have a second inner enlargement, near the siphonoglyphs. There are no rudimentary or narrow mesenteries between the larger ones in the gastric region.

Fishing Banks, off Newfoundland, in deep water. It was brought up on the trawl hooks of a Gloucester, Mass. fishing vessel, but no record of the precise locality was given.

ART. XLIV.—*A Preliminary Note as to the Cause of Root-Pressure;* by ROBERT G. LEAVITT.

THE following suggestion is made in the hope of breaking a way toward the proper understanding of the nature of so-called root-pressure. The hypothesis here tentatively proposed seems to coördinate certain of the results obtained by Sachs, Clark and others, which after several years still stand in apparent need of explanation.

Van 't Hoff's interpretation of the exact determinations of osmotic pressures made by Pfeffer, de Vries, Tammann and others, which interpretation is generally accepted by physicists and by Pfeffer himself, though still neglected by the majority of writers on vegetable physiology, is here assumed as the basis of the discussion on the physical side. Unfamiliarity with this theory on the part of many botanists may warrant a condensed statement of its central principles.

Solutions (the term being applied to the dissolved substances, exclusive of the solvents) act in all ways, both qualitatively and quantitatively, as gases, exerting pressure against containing water-, or other, surfaces by an inherent expansive force. The laws of solutions are identical in form, if "solution" be substituted for "body of gas," with the laws of Boyle, Charles and Avogadro for gases. Quantitatively considered, "dissolved substances exert the same pressure, in the form of osmotic pressure, as they would exert were they gasified, at the same temperature, without change of volume."

The distention of a turgid cell is then due to the pressure of organic matters in the cell sap, unable to escape or able to escape only with difficulty. The entrance of water is a consequence, not cause, of the osmotic pressure. A sufficient supply of water at hand is, to be sure, a necessary condition for allowing the osmotic force to act and push the cell-wall outwards, since the boundaries of the solvent, equally with definite membranes, limit the molecular wandering of the solution.

The movement of water up the stem of the thistle-tube, in the familiar experiment, is caused by the upward pressure of the solution against the free surface of the water; the water and the membrane below both being passive accessories in the operation. If the stem were crossed by diaphragms permeable by both water and solution, these would not constitute osmotic membranes in the sense of occasioning osmotic stress and flow of water; osmose and filtration of water would proceed through them. If the stem, however, were crossed by a membrane permeable by water but not by the solution, both would be stopped, and no exfiltration of the water by action of the confined osmotic substance is conceivable.

Osmose being defined as the diffusion of a solution through a membrane, and water being in no sense a solution, "endosmose of water" is mistaken phraseology. Some other appropriate term should be employed, such as infiltration. "Osmotic pressure" is unmistakable, but it is well to keep in mind that pressure arises through failure of the solution to accomplish osmose.

Coming now to the plant-body as an osmotic machine, we may distinguish two categories of osmotic pressures with their consequent filtrations of water, according as (1) the solutions are confined within single (living) cells, or (2) the osmotic substances permeate the whole cellular system from root-tip to leaf. The first may be termed localized or intracellular osmotic pressure, the second general internal, or sap-pressure.

The difficulties involved in ascribing root-pressure to localized osmotic action of the root parenchyma are well understood, and need not be dwelt upon. Some of them seem to be obviated by attributing the phenomenon in question to general internal osmotic pressure. The root immersed in the wet soil may be compared to the thistle-tube of the common experiment. The root-surface or surface tissue will then answer to the membrane stretched over the mouth of the tube. Tracheæ, tracheids, intercellular spaces, and all parts dead or alive through which sap-solutions percolate, may answer as a whole to the interior of the thistle-tube. Soil water may correspond to the water in the outer dish and sap with its contents, to water with its salt or sugar inside the thistle tube. The water in the stem of the latter, rising by reason of upward osmotic pressure on its free surface, overflows in an osmotically driven stream. The outflow from the root, when the stem is cut off, may have a like cause. In the artificial apparatus the solution washes out with the stream, and the end of the process ensues. In the case of the living apparatus stores of insoluble organic matters (as starch) are present, from which the reduced fund of osmotic substances (as sugars) may be replenished from time to time by action ot enzymes, causing periodic overflows of the kind described by Sachs. The flows would naturally decrease in volume as the stock of reserve materials became gradually exhausted.

The observations of Sachs on the effect of heat in increasing absorption, and of Clark on pressure in tree-trunks, accord well with the supposition that both kinds of phenomena are due to general osmotic sap-pressure.

The agency of osmotic sap-pressure as more or less important among several possible factors in maintaining or restoring the continuity of free water between root and leaf during transpiration, is here suggested. So-called negative pressure may probably be shown to be compatible with a simultaneous osmotic sap-pressure of considerable intensity, when the supply of water at the root falls below the demand.

Harvard University, April 14, 1899.

ART. XLV.—*A Study of Some American Fossil Cycads.** Part III. *The Female Fructification of Cycadeoidea;* by G. R. WIELAND. (With Plates VIII–X.)

Introduction.

FEMALE fruits of fossil Cycads from America have not been hitherto described. European specimens, however, have furnished two nearly perfect examples which have been made the objects of careful research and discussion during the past thirty years. In fact, the study of *Bennettites Gibsonianus* by Carruthers,[3] and Solms-Laubach,[8, 9] together with Lignier's[12] investigation of *Bennettites Morièrie*, may well be considered one of the triumphs of modern paleobotany. As a result, the structure of the cycadeoidean seed-bearing organs is nearly as well known as that of the existing cycads.

The subject of female fructification, as far as treated before the announcement of the discovery of the corresponding male flower in Part I of these contributions, has been amply reviewed by Seward. Hence it is only necessary to state briefly that the object of this preliminary paper is to deal with several quite perfect cycadeoidean fruits as observed in certain trunks from the Jurassic of the Black Hills. These, it will be seen, are in all essential characters similar to the English, French, and Italian examples of *Cycadeoidea*, of which the best known are *Cycadeoidea* (*Williamsonia*) *gigas*, Carruthers, and *C.* (*Bennettites*) *Gibsonianus*, Carr., both from the lower Greensand of the Isle of Wight, *C.* (*Bennettites* and *Williamsonia*) *Morièrie*, Saporta, from the Oxfordian of Normandy, and *C. etrusca*, Capellini and Solms-Laubach, from the Etruscan Necropolis at Marzabotto, the original locality of which is unknown. The American forms are so analogous to the several foregoing species as to preclude more than specific difference, and thus add one more argument in favor of the approximately synchronous existence of these highly specialized forms on both continents. Whether or not final study will permit their retention in a single genus is, however, a doubtful question that need not now be taken up; nor can the subject of the bracts and peduncles be treated in the present paper, although recent studies by Scott[20] make it quite certain that their investigation will furnish valuable data.

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* Part I of these studies appeared in this Journal for March of this year, and Part II in the April number following. The numbers refer to the list of papers given at the end of Part I.

The Fruit of Cycadeoidea Wielandi, Ward (MS.). ♀

General Features.—Cycadean trunk No. 77 of the Yale collection, illustrated on Plate VIII, figure 1, is the female type of the foregoing species. It is a finely preserved example, bearing laterally, in addition to ten apparently fresh scars left by the shedding of ripened fruits, forty more or less complete seed-covered fruits, which were mature or nearly so when fossilization began. The shape of these fruits is ovoid, and their average size is from 3·5 to 4^{cm} in length by 2 to $2·5^{cm}$ in diameter. In both size and form, they resemble the fruit of *Cycadeoidea* (*Bennettites*) *Gibsonianus*, Carr., though the seeds are less elongate in the latter species.

The embryos of the seeds of this trunk prove to be the only important structures not present in unusual clearness of detail. Moreover, this was the first seed-bearing cycad to be described as such from American formations, as well as the one upon which these studies were begun. Hence it is made the first type of female fructification in American cycads, although other more perfect supplementary material has since been studied.

A close examination of the specimens represented in the plate affords interesting facts concerning the fruit-bearing habit of *Cycadeoidea*. In their various stages of growth, maturity, and dehiscence, the fruits are borne on short peduncles approximately of the same length, thus indicating that the mature fruit was not protruded further from the trunk by subsequent growth. Nor does there seem to be any order of maturity from the base to summit of the trunk in either direction.

In several other related trunks most of the fruits have been shed, being represented by scars only; while a few floral axes remain undeveloped or in an atrophied condition. Still other trunks of this and associated species are barren or bear embryonic fruits. The latter condition is of considerable importance, as it will permit a developmental study of the organs. The only general conclusion to be drawn at present, however, is that there was no sharply limited period when these cycads matured their flowers. Apparently there was a progressive maturity of fruits through an entire season, which was followed by several seasons of unfruitfulness.

From the characteristic form and sculpturing of the scars representing the position of the matured fruits, it would seem that the latter were shed by the parent plant with their parts intact and often with few or no accompanying bracts.

Following fructification and the shedding of ripened fruit, there was a closing up of bracts about the receptacle, with more or less obliteration. The appearance of the fruits as apparently mature on the trunk, and of the scars mentioned above, are fairly well represented in figures 1 and 2, Plate VIII. In all cases where the seeds are exposed the tips of the bracts are necessarily more or less worn or broken away.

The lateral, or proliferous, inflorescence here exhibited is noteworthy. In this respect these specialized culminant fossil types vary from all the higher existing forms which are sympodial, and partially agree with the genus *Cycas*. The latter is the most primitive living form, and has its peduncles distributed between the petioles for some distance below the apex of the trunk. Among the various species represented in the Yale collection there are none showing the sympodial type and but few flower-bearing examples which have no flowers on the lower half of the trunk, though the male trunks incline to bear the most of their flowers near the summit.

Special Organs.—As stated above, these fruits are ovoid bodies borne on short peduncles. The latter take their origin on the trunk after the manner of the petioles and terminate in an elongated receptacle. This bears laterally an involucre of slender enveloping bracts, and terminates in a "parenchymatous cushion," as termed by Carruthers.[3] The face of this cushion, or secondary receptacle, is flatly convex and bears two series of densely set organs, much modified according to their central or more peripheral position. The first of these are the seed-bearing stems, or essential organs, while the second are merely interstitial and quite analogous to chaff. They are termed "interseminal scales" by Lignier.

The disposition of these parts is illustrated in the longitudinal sections, figures 10 and 12, Plate IX, and in the corresponding transverse sections, figures 9 and 11 of the same plate, as well as in the several transverse sections on Plate X.

In this arrangement of densely set seed-bearing stems and surrounding scales borne on a fleshy bract-enveloped receptacle, there is a certain simulation of the flowers of *Compositæ*.

Histological Structure.

The Parenchymatous Cushion.—This is composed of soft parenchyma centrally, but becomes more dense peripherally. Though no well-marked bundles have been noted, sparse and irregularly branching strands of scalariform cells apparently supply the seed stems. As there is usually a cleavage line, or zone of imperfect preservation, just at their origin, this could not be readily determined. The strands may scatter and end in the cushion. They are illustrated by Carruthers in his description of *Bennettites Gibsonianus*.

Seed Stems.—These are very closely set on the cushion, and as it is difficult to separate their elements from those of the interseminal scales in the longitudinal sections, they may be best studied in transverse sections. Such a section from the middle of the fruit is shown in figures 14 and 16, Plate X, where the stem is seen to consist of a central vascular bundle enclosed in an endodermis which is surrounded by a broad woody outer layer, or xylem zone, the "enveloppe tubuleuse" of Lignier.

Each seed stem is uniformly surrounded by from 5 to 6 interseminal scales. A series of transverse sections from the base to the summit shows no variation from this general arrangement, although there is a slow diminution in the diameter of the stems, accompanied by marked changes in the cell conformation of the xylem zone. In this and other species, there is often at the base a strong compression of the surrounding scales, while the xylem areas are more or less polygonal and composed of cells quite regularly subrhombic in section. Of these, from 30 to 40 may be counted radially, as shown in figure 4, Plate VIII. Towards the summit there is a constant increase in the size and regularity of these cells, which finally become quite round, accompanied by a decrease in the width of the xylem band, until at the base of the seeds it consists of but two layers of cells surrounding the central bundle, which remains constant in character.

This bundle is well illustrated in the enlarged view given in figure 15, Plate X. Centrally there are from 3 to 10 small woody elements. These are enveloped in soft parenchyma, not preserved in all specimens, and the bundle terminates in a well-marked endodermis. Such concentric bundles recall the somewhat similar structures seen in many ferns. The atrophied peduncles, or those lacking a well-marked central bundle, described by Lignier in *C.* (*Bennettites*) *Morièrie*, have not been observed thus far. The interesting case of bifid seed stems, or those with two central bundles within the same tubular, or xylem zone, however, rarely repeats itself in the present specimens.

It may be mentioned that while the figure of the transverse section of the seed stems, "vascular cords," given by Carruthers is a faithful one, its being cut too near the base, where there is much compression of the several elements, prevented a true conception of their significance. Only at some distance above the base does the clear differentiation of parts seen in figure 14, Plate X, appear. Judging from the transverse section by Carruthers, just mentioned, and the additional one given by Solms-Laubach, the tubular layer, or xylem zone, of *C.* (*Bennettites*) *Gibsonianus* was composed of more angular cells than in the case of the present specimen.

Lignier gives a section of a seed stem from near a seed base (peduncle, figure 27, Plate II),[12] in which the tracheidal cord is followed by fundamental tissue, and this by a layer of cells (*assize colorée*), which is in turn surrounded by a single row of cells laterally dovetailing. This alteration at the seed bases has not been observed as yet by the writer, and no doubt must stand as one of the specific variations between the foregoing species.

Interseminal Scales.—Five or six of these commonly surround each seed stem, and rise beyond the seeds, their tips expanding to form the rounded summit of the fruit. Figure 13, Plate X, displays a transverse section of one of these organs cut near its middle height. In the case of cycad No. 77, figure 14, Plate X, the parenchyma surrounding the central vascular strand is not preserved; but the central strand, the large subepidermal cells (much less continuous in this species than in *C. Morièrie*), and the epidermis, are so uniformly present as to differentiate these tissues as absolutely as any staining. From the base toward the summit, as the seed stems decrease in diameter, the scales increase in size by the enlargement of the cross area of the parenchyma cells, which are usually rounded in section and quite elongate. Beyond the seeds, the cells composing the expanded summits are entirely lignified. In the seed zone, the scales are also more or less lignified and often very thin and flat as they pass between the seeds, where it is sometimes difficult to differentiate them from the seed coats. Exterior to the outer seed stems there is a flattened overlapping series of scales, forming a kind of lateral wall of the fruit several scales in depth. The distal portions of these modified scales are elongate, tetrangular, and lignified, as they appear on the fruit surface.

It is difficult to detect the several elements of the scales in longitudinal section. That some of the xylem cells are spirally marked is certain, and that there is an occasional scalariform marking is also certain. The woody elements of these scales regularly take their origin below that of the cells of the xylem zone of the seed stems, and in figure 5, Plate VIII, are seen extending down into the parenchymatous cushion as small projecting brushlike groups.

It need scarcely be pointed out that there is an analogy between these scales and the central bundle of the seed stems, the variation being in a uniformly large central strand, the addition of a broken subepidermal layer with apical sclerotization, and the presence of occasional ducts in the case of the scales.

The Seeds.—The seeds thus far observed in the present and other species show much variety of preservation. Their study is therefore a difficult one, requiring time, especially for the purpose of comparing a large number of the same and different species, and determining how far the structures supplement each other. Hence no detailed account of seed structure will be now attempted, although the appended figures, which in reality are but little diagrammatic, are introduced.

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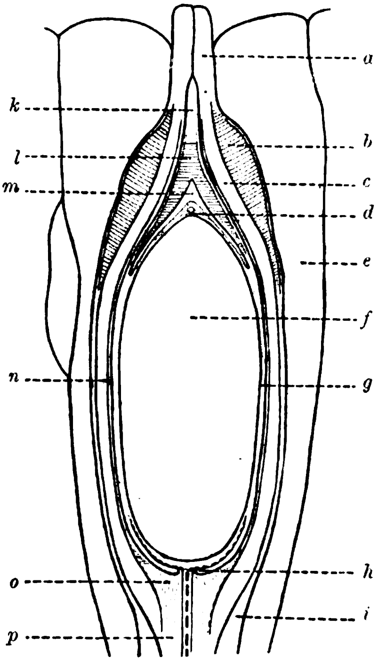

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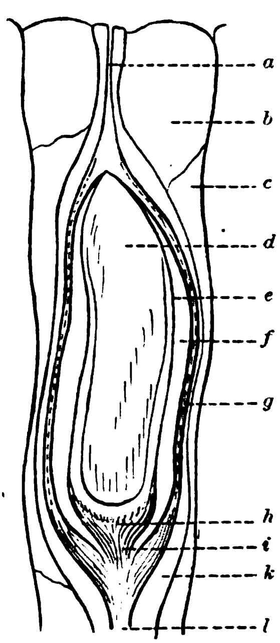


FIGURE 1.—*Cycadeoidea* (*Bennettites*) *Morièrie*, Saporta ♀; longitudinal section of seed. (After Lignier.)

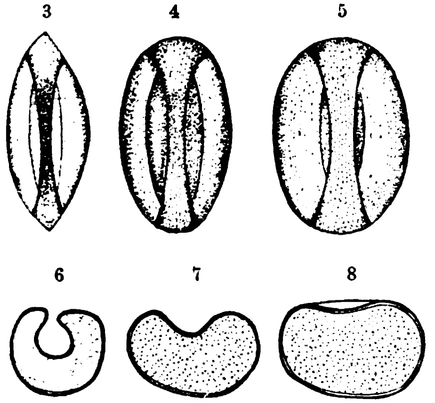
a, micropylar tube; *b*, prismatic layer; *c*, pulpy tissue; *d*, corpuscular mass; *e*, interseminal scales; *f*, embryo space; *g*, remains of nucellus; *h*, chalaza; *i*, tubular layer (= xylem zone); *k*, micropylar canal; *l*, nucellar beak; *m*, pollen chamber; *n*, fibrous stratum; *o*, basal expansion of *n*; *p*, parenchyma of seed stem.

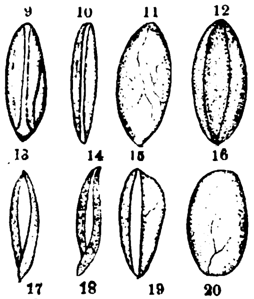
FIGURE 2.—*C. Wielandi*, Ward ♀; longitudinal section of seed. × 12

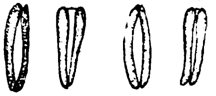
a, micropylar tube; *b*, interseminal scale; *c*, the same; *d*, cotyledons; *e*, fibrous layer ending below the chalaza in an expanded base of scalariform tissue; *f*, a structureless zone; *g*, stringy remains of cells lignified and slightly expanded below; *h*, chalaza; *i*, woody scalariform tissue; *k*, prismatic outer layer of seed ending in xylem zone; *l*, parenchyma.

General Considerations.

Owing to the large number of male and female examples of *Cycadeoidea* in the Yale collection, their proper correlation will require considerable time. Nevertheless, several facts of importance present themselves for mention. A number of species bear fruits of the type represented in the well-known figure of *C. etrusca* given by Capellini and Solms-Laubach (Plate IV).[10] These heart-shaped fruits have very closely set, rodlike seeds arranged prismatically on a short, fleshy axis, traversed by numerous gum ducts and usually devoid of the regularly arranged seed stems and interseminal scales characterizing *C.* (*Bennettites*) *Gibsonianus*, *C. Morierie*, and *C. Wielandi.* Should there prove to be no intervening forms and no connection during developmental stages, this must be finally regarded as a strong generic difference. One of the Yale specimens not yet fully studied, but nearly related to *C. etrusca*, as far as may be judged from general features, displays seeds with well-marked cotyledons, as represented in figure 7, Plate IX. Another closely related trunk, of which the female form also is known, shows well-preserved male cones of essentially the same character as those described in Part I of these contributions. Pollen grains, both distended and dessicated, and represented in figures 9–16, are present in rare preservation. They are so like the dissociated pollen figured by Capellini and Solms-Laubach[10] in their description of *C. etrusca* that figures 17–20 in the text are introduced for comparison, as well as pollen from the living cycad *Ceratozamia*, figures 3–8. That these fossil bodies represent characteristic cycad pollen is beyond all question. Sections of the cycadeoidean cone from which the pollen of figures 9–16 was derived are given in figures 17 and 18, Plate X.







FIGURES 3–8.—*Ceratozamia longifolia*, Miquel; pollen grains. (After Juranyi.) × 610.
3, mature pollen in dry condition; 4, 5, the same swollen in water; 6–8, the respective transverse sections, or end views.

FIGURES 9–16.—*Cycadeoidea*, sp., Black Hills; pollen grains. × 250.
9, 10, 13–15, more or less dessicated grains; 11, 12, 16, normal forms.

FIGURES 17–20.—*Cycadeoidea etrusca*, Capellini and Solms-Laubach; isolated and dried pollen grains. (After Capellini and Solms-Laubach).

But one interpretation of these facts is possible—*Cycadeoidea etrusca* represents a fertilized diœcious plant, the male flower of which has now been definitely recognized in an allied species. The so-called "antheriferous tissue" noted by Capellini and Solms-Laubach hence remains an unexplained structure, possibly of much significance. Should this tissue represent a developmental stage instead of permanent structure, as certain sections made by the writer suggest, it nevertheless merits the closest examination, and may have some connection with a "corona" such as that of *Williamsonia gigas*.

Another close resemblance between the American and European species having prismatic seeds is the characteristic surface sculpturing. Figure 2, Plate VIII, is introduced here for comparison with a Bennettitean specimen illustrated by Seward (Fossil Plants of the Wealden, Plate XV, figures 5 and 6).*

Yale Museum, New Haven, Conn., April 24, 1899.

EXPLANATION OF PLATES.

Plate VIII.

Figure 1.—*Cycadeoidea Wielandi*, Ward ♀; type specimen. × ½.

Figure 2.—*Cycadeoidea* (sp.) ♀; surface sculpturing of a fruit. × 10.

Figure 3.—*Cycadeoidea Wielandi*, Ward ♀; portion of a trunk, showing scars left by the shedding of fruits. × ½.

Figure 4.—*Cycadeoidea turrita*, Ward ♀; transverse section of a seed stem (from near the parenchymatous cushion) surrounded by an unusual number of interseminal scales. × 30.

Figure 5.—*Cycadeoidea Wielandi*, Ward ♀; longitudinal section through seed stems, showing their origin on the parenchymatous cushion. × 24.

Figure 6.—Same fruit as figure 5; transverse section of seed stems near periphery of fruit. × 30. (Compare with figure 14.)

Plate IX.

Figure 7.—*Cycadeoidea* (sp.) ♀; nearly transverse section through the periphery of a fruit, cutting 5 seeds, in several of which the cotyledons may be seen. × 16.

Figure 8.—*Cycadeoidea Wielandi*, Ward ♀; longitudinal section through a fruit near the summit, cutting superimposed seeds. × 12.

Figure 9.—*Cycadeoidea Wielandi*, Ward ♀; type specimen; transverse section through fruit; showing seeds, seed stems, and interseminal scales. × 4.

Figure 10.—Same fruit as preceding; longitudinal section through seed stems and parenchymatous cushion. × 4.

Figure 11.—*Cycadeoidea turrita*, Ward ♀; transverse section through fruit, cutting a single seed obliquely. × 25.

Figure 12.—Same fruit as preceding; longitudinal section. × 4.

a, seed; *b*, densely set interseminal scales and aborted seed stems (?); *c*, the parenchymatous cushion; *d*, involucral bracts; *e*, line of dehiscence (?).

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* In the case of generic and specific names, the writer has followed Prof. Lester F. Ward of the U. S. National Museum, as the recognized authority on American cycads. Fortunately for scientific uniformity, Prof. Ward has described practically all the cycads discovered in this country.

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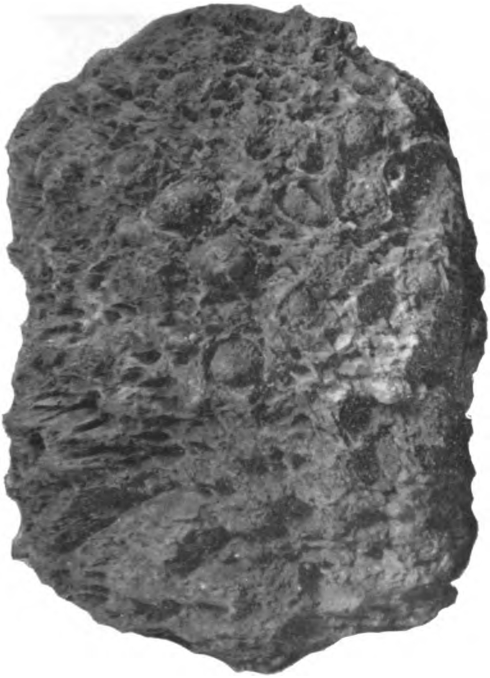

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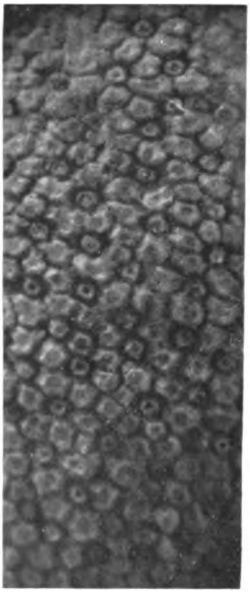

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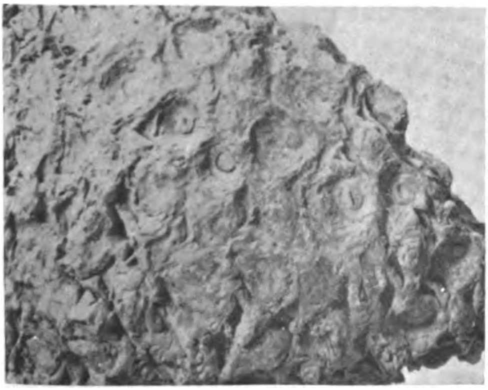

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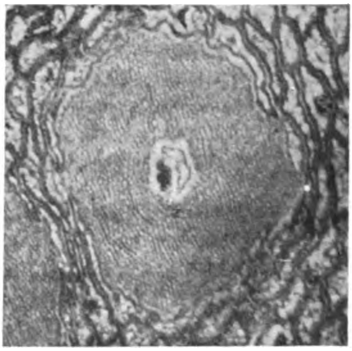

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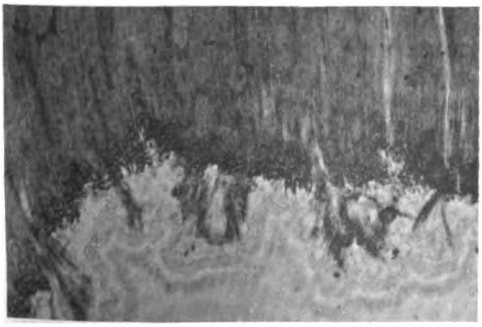

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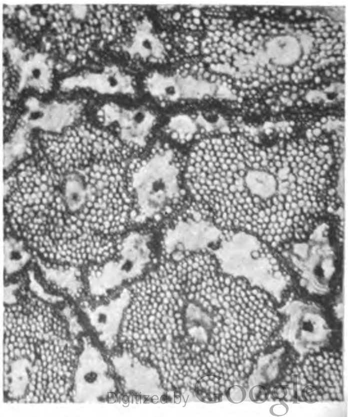

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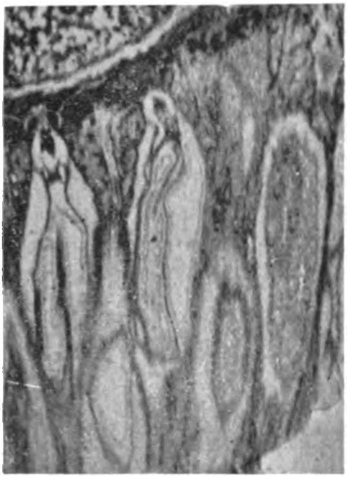

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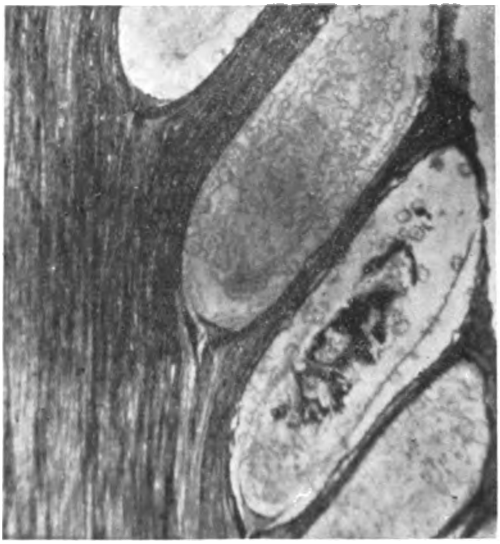

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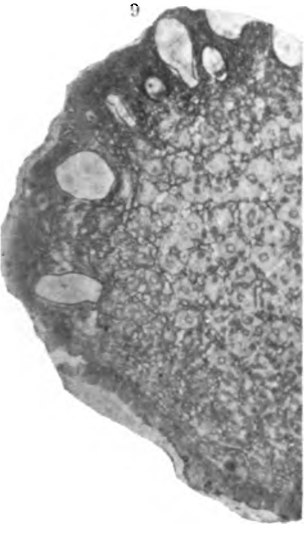

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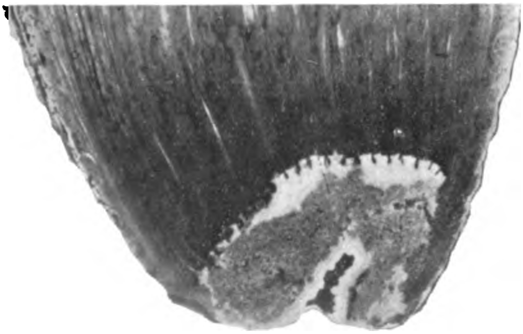

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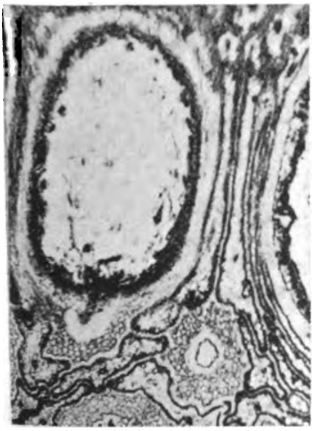

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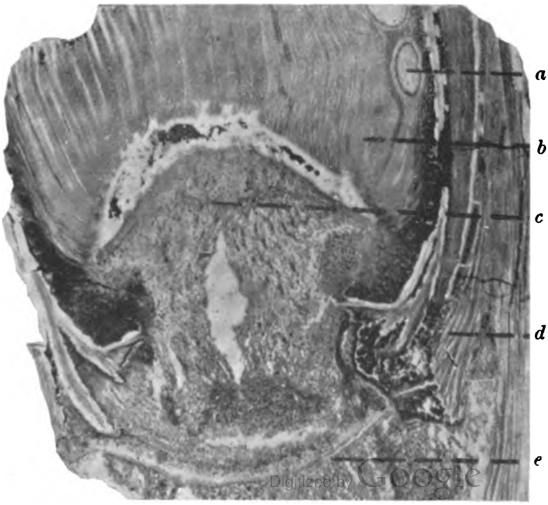

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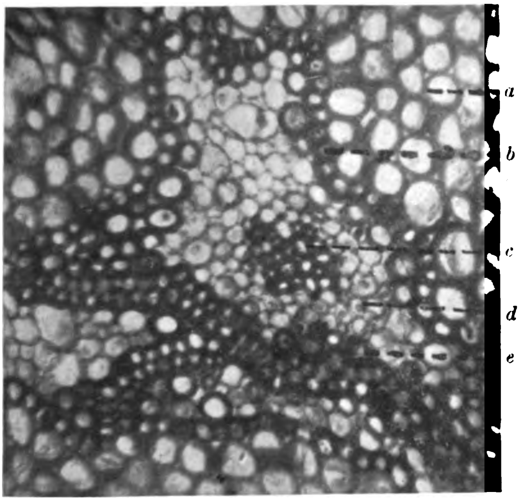

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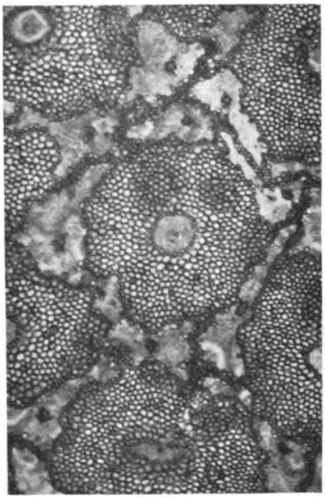

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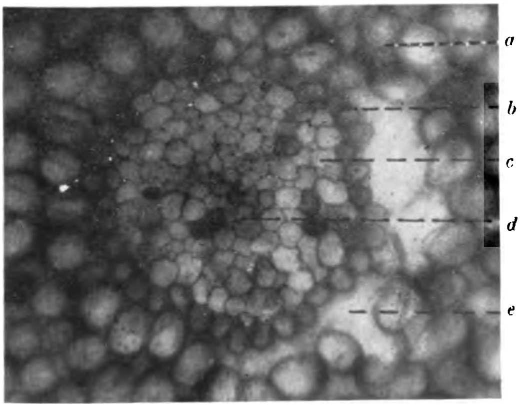

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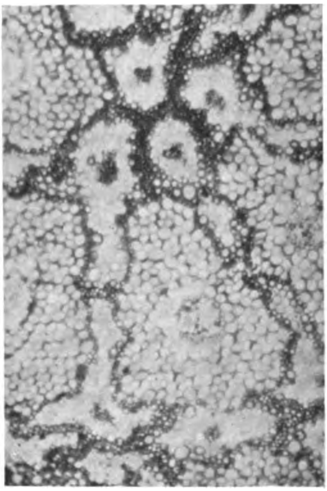

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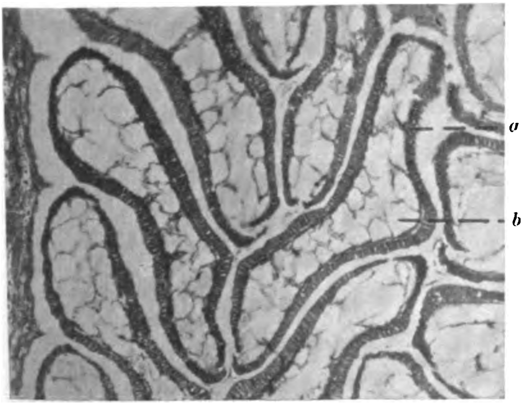

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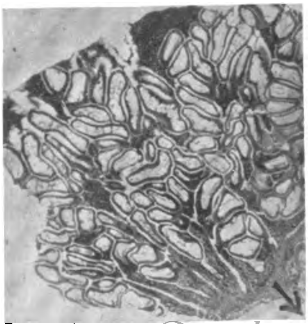

PLATE X.

FIGURE 13.—*Cycadeoidea Wielandi*, Ward ♀; transverse section of an interseminal scale. × 185.

a, xylem zone of a bordering seed stem; *b*, epidermis of the interseminal scale; *c*, xylem; *d*, parenchyma; *e*, heavy and much broken subepidermal layer.

NOTE.—Where two scales border there is a double layer of *b*.

FIGURE 14.—*Cycadeoidea Wielandi*, Ward ♀; type specimen; transverse section through seed stem and surrounding interseminal scales, no parenchyma of either of these organs being preserved. × 22.

FIGURE 15.—Same fruit as figure 13; transverse section through the central bundle of a seed stem. × 185.

a, xylem zone; *b*, endodermis; *c*, parenchyma; *d*, xylem; *e*, cellular interspace.

FIGURE 16.—Same fruit as preceding; transverse section of seed stems and interseminal scales, all elements being preserved. × 22.

FIGURE 17.—*Cycadeoidea* (sp.) ♂; transverse section through the pendent sori of a sporophyll. × 18.

a, epidermis of prismatic cells which entirely invests each sorus, the latter consisting of two parallel rows of sporangia; *b*, one of the sporangia containing pollen grains as illustrated in text, figures 7–14, page 389.

FIGURE 18.—Same as preceding, but showing a larger area. The arrow points towards the floral axis. × 3.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On Low Temperature Experiments.*—In consequence of the easy production of liquid oxygen and nitrogen in recent times, experiments at low temperatures have become common. **HEMPEL** has called attention to the fact, however, that with much simpler means than these, temperatures sufficing for the greater part of the ordinary reactions can be secured. Thus, for example, liquid carbon dioxide, now commercially very cheap, may readily be employed to show that potassium and bromine no longer react on each other at low temperatures. If the bromine be first placed in a mixture of solid carbon dioxide and ether and thoroughly cooled, and then a piece of potassium, cooled in a similar bath, be introduced into it in a small spoon, no combination takes place; though it speedily sets in as the temperature of the mixture rises. Very considerable improvements, however, are necessary in the methods of manipulation. The double-walled and exhausted globe of Dewar, therefore, has been of great service. But these Dewar globes are costly and fragile when they are of large size; and hence are not available for laboratory experiments on any large scale. The author therefore has experimented to determine to what extent a sufficient isolation can be secured in other ways. Test tubes 4^{cm} in diameter, approximately of the same size as the Dewar tubes, were placed in beakers 13^{cm} in diameter, the space between being packed with the material to be tested. Equal quantities of solid carbon dioxide and ether were placed in each of these tubes; so that at the beginning of the experiment all the vessels contained equal quantities of material at $-79°$. From time to time the temperature in the several tubes was determined by an electric pyrometer. In 5 minutes the tube packed with cotton had a temperature of $-76°$, that with wool $-77°$, that with eider-down $-78°$, and that with a well exhausted Dewar tube $-77°$. After 58 minutes these values were successively $-56°$, $-64°$, $-67°$, and $-54°$; thus showing that well dried wool and eider-down are very good insulators, being exceeded only by the best Dewar tubes. For preparing the solid carbon dioxide the author prefers a paper funnel with a wide short neck, to the upper edge of which is fastened a cylindrical bag of linen. On clasping the upper portion of this bag about the valve on the cylinder containing the liquid gas, and opening this valve, the solidified gas collects in the bag and may be readily shaken into the funnel. About 270–300 gms. of the solid are obtained from a kilogram of liquid; and since this liquid costs about 15 cents a kilogram, the solid would cost not far from fifty cents a kilogram. No advantage in yield was found to result on cooling the liquid before expansion. The lowest temperature is obtained when the solid carbon dioxide is mixed with

ether to a stiff magma.—*Ber. Berl. Chem. Ges.*, xxxi, 2993–7, December, 1898. G. F. B.

2. *On Reductions in Presence of Palladium.*—Although palladium-hydrogen has been used already as a reducing agent by Graham and by Saytzeff, yet now by a more extended study Zelinsky finds that it may be employed with great success in the reduction of bromides and iodides of cyclic alcohols, a class of compounds which hitherto it has been impossible to reduce by any of the ordinary methods. The form in which it is used is that of a palladium-zinc couple, analogous to the copper-zinc couple of Gladstone and Tribe. To form it, zinc filings are well washed with alcohol, then treated with sulphuric acid until an active evolution of gas takes place, and finally washed with water. On pouring upon them a one or two per cent solution of palladium chloride previously acidified with hydrochloric acid, a thin strongly adhering layer of palladium is deposited upon the zinc. The couple thus formed is washed with alcohol and dried. To effect the reduction, which takes place at the ordinary temperature and up to 100°, a flask provided with a reflux-condenser and dropping funnel is one-third filled with the palladium-zinc couple, this couple is partly covered with methyl or ethyl alcohol and hydrochloric acid saturated at 0° is run in drop by drop. At first the hydrogen is absorbed by the palladium; and as soon as bubbles of gas are evolved, the bromide or iodide to be reduced is added gradually, alternately with the acid. The action is controlled by regulating the quantities of material added. The evolved gases are passed through alcohol to retain any volatile hydrocarbon which may be carried over. The palladium-zinc in the flask, after washing with acid and with alcohol, is ready for further use.—*Ber. Berl. Chem. Ges.*, xxxi, 3203–5, January, 1899. G. F. B.

3. *On the Properties of Metallic Calcium.*—Further results have been communicated by Moissan on the properties of calcium. Prepared by the method already described,* the metal separates from fused sodium in hexagonal crystals which have a specific gravity of 1·85 and melt at 760° in vacuo. On solidifying, the metal is somewhat brittle, is less malleable than potassium or sodium and shows a crystalline fracture. When free from nitride, it is silver-white in color and has a brilliant surface. Heated to redness in a current of hydrogen, a crystalline hydride CaH_2 is formed. When pure, calcium is not acted on at ordinary temperatures by chlorine; though at 400° the action is decided. But if the metal contains nitride, chlorine attacks it at the ordinary temperature. At 300° it ignites and burns brilliantly in oxygen. Gently warmed in air, it burns with brilliant scintillations. It combines with sulphur at 400° with incandescence. At a red heat it unites actively with lamp-black, yielding CaC_2. Calcium gives somewhat brittle alloys with magnesium, zinc and nickel. With tin the alloy contains 3·82 per cent of calcium, has a density of 6·70, and slowly decomposes water. A crystalline amalgam is

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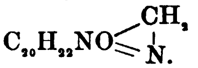
* This Journal, IV, vi, 428, November, 1898.

formed with mercury which may be distilled in hydrogen at 400°, but which forms nitride when heated in nitrogen. Heated to redness with potassium or sodium chloride, calcium sets the metal free. Water acts on calcium only very slowly, evolving hydrogen. At a red heat, it combines explosively with phosphoric oxide, and decomposes silica, yielding calcium silicide and some silicon. At 600° it reduces boric oxide to boron. Nitric acid when strong acts on calcium very feebly, though when diluted the action is rapid. Fuming sulphuric acid is reduced by the metal. Heated to dull redness in ammonia, a mixture of hydride and nitride is produced. In liquefied ammonia at —40°, calcium ammonia is formed, a reddish brown solid.—*C. R.*, cxxvii, 584–590, October, 1898. G. F. B.

4. *On New Bases from Strychnine.*—It has been noticed by **Tafel** that when a current of five amperes at a potential of three and a half volts is passed through a solution of 30 grams of strychnine in 180 grams of concentrated sulphuric acid diluted with 120 grams of water, two poisonous bases are produced which he calls tetrahydrostrychnine and strychnidine. After passing the current for two hours, the liquid, diluted with four volumes of water, is nearly neutralized with barium carbonate, filtered, heated to boiling and treated with barium hydrate in slight excess. The strychnidine is contained in the precipitate while the filtrate contains the tetrahydrostrychnine. Strychnidine crystallizes from alcohol in stellate groups of colorless needles, fusing in vacuo at 252° and having the structural formula



$C_{20}H_{22}NO \lessgtr \begin{array}{l} CH_2 \\ \;| \\ N. \end{array}$

It boils at 290°–295° under 14^{mm} pressure, and may be distilled undecomposed, the distillate solidifying to a crystalline mass. It is sparingly soluble in water, but dissolves more freely in alcohol, benzene and chloroform. A 6·4 per cent chloroform solution has a specific rotatory power $[\alpha]_D = -8{\cdot}28^\circ$ at 20°. Dissolved in sulphuric acid, it gives color with oxidizing agents. Its aqueous solutions with excess of acid become intensely red with potassium dichromate, hydrogen peroxide, ferric chloride and sodium nitrite. Tetrahydrostrychnine $C_{20}H_{22}NO(NH).CH_2.OH$ crystallizes from alcohol in colorless prisms, containing a molecule of the solvent, which it loses at 100°. It dissolves in 280 parts of water at 20°, the solution being strongly alkaline. It resembles strychnidine in its action with sulphuric acid and oxidizing agents, but gives a wine-red solution when its hydrochloric acid solution is treated with chromic acid or ferric chloride. Strychnoline, obtained by reducing dioxystrychnine in amyl alcohol with sodium, and dihydrostrychnoline, produced by passing a current through a solution of deoxystrychnine in sulphuric acid, are also described.—*Liebig's Annalen*, ccci, 285–348, August, 1898. G. F. B.

5. *A History of Physics in its Elementary Branches including the Evolution of Physical Laboratories;* by **Florian Cajori**,

Ph.D. 8vo, pp. viii, 322. New York, 1899 (The Macmillan Company).—In this book the author has attempted a somewhat condensed review of the progress in physical science from the earliest times to the present. In the preface he quotes Ostwald's statement to the effect that a defect attaching to present scientific education is the absence of the historical sense and the want of knowledge of the great researches upon which the edifice of science rests. It seems to be fully recognized that the historical development of a subject is an essential aid to the proper understanding of it. It may be a question, however, whether this historical treatment should not be given in connection with the subject discussed rather than have a separate course devoted to it. In this book the history of physics is divided into time epochs, i. e., that of the Greeks, the Romans, the Arabs, the Middle Ages, the Renaissance, the Seventeenth Century, the Eighteenth Century and the Nineteenth Century; closing with a chapter on the Evolution of Physical Laboratories. This method seems to necessitate considerable repetition, light for example being considered six times. Possibly a physical classification would entail less repetition and be handier for reference. A wide range of references has been made use of and these are given in foot-notes. The book will undoubtedly be of use to students and teachers of physics, for whom it was intended.

6. *The Electrolytic Interrupter.*—Much interest has been excited by Dr. A. Wehnelt's new interrupter for induction coils, which consists of a lead plate, the cathode, and a platinum point, the anode, immersed in dilute sulphuric acid and connected with an electrical source of comparatively high voltage. At a recent meeting of the Physical Society in London, March 10, Mr. A. A. CAMPBELL SWINTON described his experiments with this interrupter. It was found that the minimum working voltage was twenty-five volts. The spark-pitch varied with the length of the platinum terminal wire. The wire must be immersed in the dilute acid before the circuit is closed, otherwise the action is not obtained. The interrupter becomes fatigued in a quarter of an hour and then the platinum becomes red-hot. The interrupter would be very effective for X-ray work if it did not heat the Crookes tubes. Mr. Swinton suggested the use of the interrupter for the production of Hertz waves. Professor Oliver J. Lodge thought that it would not be effective for this purpose since the air would not quickly regain a non-electric condition. The interrupter will work with an alternating current but with half the efficiency, apparently allowing only one-half the alternations to pass. A well-known arrangement, however, of circuits might give a greater efficiency.—*Nature*, March 16. J. T.

7. *Measurement of slow electrical oscillations.*—W. KÖNIG discusses previous methods of receiving the sparks from an induction coil on lamp-blacked rotating discs, and describes an efficient method of measure, which consists of a tuning fork provided with a stylus which serves both to register the time on a blackened

disc connected with a pendulum and to serve as a terminal to deliver the spark to the moving disc. With this apparatus he finds that he can follow changes of potential under twenty volts. He finds that the electrostatic capacity of the bobbin of the induction coil is of the order 16×10^{-12} farad. The working of the iron core of the coil diminished with increasing number of vibrations.— *Wied. Ann.*, No. 3, 1899, pp. 535–562. J. T.

8. *Electric waves on wires.*—W. D. COOLIDGE has succeeded in photographing electric waves on wires by using a vigorous exciter—Blondlot, or Tesla transformer. The photographic lens was placed above the wires, which were horizontal. The nodes and ventral segments are clearly distinguished in the photographs. — *Wied. Ann.*, No. 3, 1899, pp. 578–591. J. T.

9. *Absorption of the X-rays by air.*—Since very short ultraviolet waves of light are absorbed by air, it is an interesting question to consider the absorption of the X-rays by air. Some recent experiments by Prof. Trowbridge and Mr. J. E. Burbank in the Jefferson Physical Laboratory instituted to study this question show that the difference of absorption of a column of air thirty inches in length at atmospheric pressure and a column of air of the same length at four millimeters pressure cannot be distinguished by the use of a fluoroscope. With cathode rays the difference is as thirty-three to one. That is, the absorption is thirty-three times as much in air at atmospheric pressure as at four millimeters pressure. The electrostatic effects in the exhausted tube thirty inches long are very beautiful and cease when the concave mirror of the X-ray tube becomes the positive terminal. J. T.

10. *Die Optischen Instrumente der Firme R. Fuess; deren Beschreibung, Justierung und Anwendung* von C. LEISS; pp. xiv, 397, with 233 text figures and three photo-plates. Leipzig, 1899 (Wm. Engelmann).—Very important advances have been made within recent years in the methods and apparatus applicable to crystallographic and optical investigations. The present volume, giving an account of the instruments furnished by the firm of R. Fuess (Berlin), is very thorough and complete and will be of great value to all working in this field. There are described here, for example, a number of forms of spectrometers and various types of apparatus to be used with them, as, for example, the new spectral arrangement of Wülfing, giving homogeneous light of different wave lengths. The reflectometers, spectrographic apparatus, goniometers, microscopes, are also fully and minutely treated of. The chapter giving an account of the different forms of apparatus for projections with electrical lamps is particularly interesting and timely. The volume is not simply a catalogue of instruments, but gives full descriptions of the method of use applicable in each case, with references to the original papers. The worker is thus told not only what instruments are to be had, but when he is supplied with them, how they are to be adjusted and used in practical investigations.

II. Geology and Natural History.

1. *Note on a Bridger Eocene Carnivore;* by O. C. Marsh.*—A reëxamination of the three species of the genus *Limnocyon* described by me in 1872 (this Journal, vol. iv, pp. 122, 203, and 204), leads to the conclusion that the type is in all probability to be referred to the genus *Sinopa*, Leidy, from the same horizon. While this statement applies to *Limnocyon verus*, the species first described, yet a second species of the genus, *Limnocyon riparius*, described by me in the paper cited, is undoubtedly distinct, and cannot be placed in any known genus of Eocene Carnivora. Since the type species of the genus, however, is thus shown to belong to *Sinopa*, the generic name *Limnocyon* must be abandoned and another substituted. I therefore propose the name *Telmatocyon*, basing the genus on the remains referred to *Limnocyon riparius*.

The generic characters may be stated as follows:

Dentition: $I_{\overline{3}}$, $C_{\overline{1}}$, $Pm_{\overline{4}}$, $M_{\overline{2}}$; two lower molars subequal in size and tuberculo-sectorial in pattern; internal cusps of these teeth considerably reduced, as in *Sinopa;* jaw very straight on inferior border, not unusually deep, but relatively thick and heavy, symphyseal portion abrupt and robust; first superior molar with external cusps well separated, and not closely approximated as in *Sinopa*.

This genus thus differs from the contemporary *Viverravus*, in the unreduced condition of the second lower molar as well as in the character of the jaw; from *Vulpavus*, in having two instead of three lower molars; and from *Sinopa* as already indicated.

2. *The Age of the Franklin White Limestone of Sussex County, New Jersey;* by John Eliot Wolff and Alfred Hulse Brooks, Eighteenth Annual Report of the U. S. Geological Survey, 1896–97, Part II, pp. 425–457, 1898.—Messrs. Wolff and Brooks have made a careful study of the white limestone of Sussex County, which, with the blue limestone of the same region, has been the subject of many papers of those attempting to determine the age of the limestones. Mr. Nason, in 1890, gave at the time what seemed to be conclusive evidence of the Cambrian age of the white limestone, attributing its crystalline condition to the intrusion of igneous rocks, and also maintained that the white and blue limestones passed one into the other. The present writers have reached the conclusion that the white limestones are pre-Cambrian in age, and that the quartzite and blue limestone are Cambrian. Their conclusion regarding the relationship of these is as follows: "That the white limestone was deformed and metamorphosed to its present condition and partly eroded before the basal member of the Cambrian series was laid down; that the

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*This note was prepared by Dr. J. L. Wortman, who first called Professor Marsh's attention to the points of synonymy as here given. The matter was left incomplete at the time of Professor Marsh's death.—Ed.

deformation which the area has suffered since the deposition of the Cambrian, which has manifested itself in folding and faulting, has been but slight compared with the pre-Cambrian deformation ; and that the Cambrian rocks overlie the white limestone, as well as the gneisses, unconformably. As a result of our observations, we are compelled to adopt the pre-Cambrian age of the Franklin white limestone." H. S. W.

3. *West Virginia. Geological and Economic Survey.*—Professor I. C. White, the State Geologist, has issued a map of West Virginia, compiled by Russell L. Morris, C.E., on the scale of 10 miles to the inch, on which are given the location of oil pools, natural gas wells, and the approximate distribution of the New River, Alleghany or Kanawha River, and Pittsburg coal areas. The map is not complete, but is issued as a preliminary one only. H. S. W.

4. *Alabama Geological Survey. Iron-Making in Alabama. Second edition ;* by WILLIAM BATTLE PHILLIPS, pp. 1–380, 1898.—This is a second edition of the report published in 1896, containing new statistics regarding the products of the State. Several new chapters have been added, among them additional information as to the coal industry, compiled from the report by James D. Hillhouse, State mine inspector. H. S. W.

5. *The Development of Lytoceras and Phylloceras*, by JAMES PERRIN SMITH, Pro. Cal. Acad. Sci., 3d Ser., Geol., vol. i, pp. 129–160, plates xvi–xx, 1898.—The two genera Lytoceras and Phylloceras are chiefly interesting "because they are simple, unspecialized genera, long-lived, little changed, and yet with the power of giving off other variable branches. They are the two longest-lived genera of ammonites, ranging from about the end of the Trias to the Upper Cretaceous, at least seven millions of years by a conservative estimate." The author has prepared beautiful plates illustrating the sutures of the protoconch and following stages of growth ; and concludes from his studies that "these two genera come from a common origin, and follow the same paths up to *Nannites*, where they part company, each going through a stage corresponding to that genus, but to different species under it; both go through *Monophyllites* stages, but here again analogous to different groups and even different subgenera. There the resemblance ceases, and they develop into different families probably by the middle of the Trias, for in the upper division of that formation *Megaphyllites* and *Monophyllites* are sharply distinguished from each other. In the life-history of these two genera we have a rare opportunity of observing acceleration of development, and divergence of two nearly related stocks, whose history may be traced from the Paleozoic to near the end of the Mesozoic eras." H. S. W.

6. *Pre-Cambrian Igneous Rocks of the Fox River Valley, Wisconsin ;* by S. WEIDMAN (Wis. Geol. and Nat. Hist. Surv., Bull. III, Science, Series 2).—This is a geologic and petrographic description of three areas of igneous rock, which appear to have been islands during the deposition of Cambrian sediments. They consist of an ancient rhyolite, a rhyolite changed to gneiss and a

granite, which probably represent phases of a parent magma. The various changes induced in these rocks through mechanical deformation in two of the areas and through chemical alteration alone in the third have been carefully studied and many features of interest are developed. L. V. P.

7. *West Virginia Geological Survey*, vol. 1; by I. C. WHITE, State Geol. (Morgantown, West Va., 1899, 8°, 392 pp.)—In addition to the administrative report this volume contains a discussion of magnetic declination for the state with description of meridian monuments by R. U. GOODE. The State Geologist himself contributes a list of levels above tide and a particularly valuable report on the petroleum and natural gas of the state. This is treated both from theoretic and practical standpoints and will be found of great service to those engaged in a study of these products. It is to be hoped that the state will continue the survey and permit the publication of other valuable material which has been accumulated. L. V. P.

8. *A new and interesting olivine-melilite-leucite rock.*—The rock of one of two small volcanic cones discovered by E. Clerici at San Venanzo in Umbria, about half way between Orvieto and Perugia, has been described by V. SABATINI in a note (dated September, 1898) in the Bolletino del Reale Comitato Geologico for 1898, as a leucitic melilitite with olivine. Olivine occurs as phenocrysts, and the groundmass is composed of melilite, leucite, black mica, and a little pyroxene, nephelite and magnetite, feldspars being absent. The melilites are zonally built, the interior being optically positive and the exterior negative. Sabatini proposes for this type the name *Venanzite.*

At the meeting of the Berlin Academy of Sciences held Feb. 9, 1899 (Sitzungsberichte, vii, p. 110, 1899), Prof. Rosenbusch read a paper on "Euktolite, a new member of the theralitic effusive magmas." This rock is identical with that of Sabatini, coming from the same locality, and his description is practically the same though more detailed, and with chromite and perofskite added to the list of component minerals. An analysis gave:

SiO_2 41·43, TiO_2 0·29, Al_2O_2 9·80, Fe_2O_3 3·28, FeO 5·15, MgO 13·40, CaO 16·62, Na_2O 1·64, K_2O 7·40, H_2O 1·11 = 100·12. P_2O_5 none. Sp. gr. = 2·758.

He compares it with the madupite of Cross, leucitites, and leucite and melilite basalts, all of which belong to his theralitic magmas. The name is derived from εὐκτός, desired, since it is "a desired example for the validity of my representation of the intimate connection of the eruptive rocks throughout the world." Sabatini's name Venanzite antedates Euktolite by about five months and on the grounds of priority is unquestionably the one by which this interesting type should be known, especially since it is formed from the type locality, in accordance with modern usage in petrography, and does not involve the tacit acceptance of any theory, however generally recognized.

H. S. W.

9. *Deuxième Mémoire sur les Algues Marines du Groenland;* by L. Kolderup Rosenvinge. Meddelelser om Gronland, xx, pp. 1–125, pl. i and 25 figs., 8°. Copenhagen, 1898. *Om Algenegetationen ved Grφnlands Kyster;* ditto, pp. 131–242.—The paper first named is an important supplement to the author's Groenlands Havalger published in 1893. The material studied included the collections made by N. Hartz, principally at Scoresby Sound during the expedition to East Greenland under Lieut. Ryder and those made by A. Jessen and C. Ostenfeld in West Greenland, besides a few smaller collections. Of the algæ of the eastern coast, which had been less thoroughly explored than the western, only 32 species had been previously enumerated, but in the present work the number is estimated at 82 including several new species. The number of species previously known on the west coast was 143, which number is now increased to 167 including in the enumeration the species reported by Kuckuck from Umanak collected by Vanhoffen. The Lithothamnia were revised by Foslie. Among the novelties are three new genera, Ceratocolax, Dermatocelis and Arthrochœte, each represented by a single species of parasitic habit. The paper is well illustrated and the notes are full and suggestive. The second paper by Dr. Rosenvinge is a valuable contribution to our knowledge of the distribution of the marine floras of the North Atlantic, which gives details as to the temperature and other factors which affect the growth of marine plants and tables showing the relations of the Greenland flora to those of northern Europe and the Atlantic coast of North America. In spite of the remoteness and inclemency of the Greenland coast, thanks to the publications of Rosenvinge, Kjellman and other Scandinavian algologists, its marine flora is more accurately known than that of any other portion of the Atlantic coast of America. W. G. F.

10. *Monographie des Caulerpes;* by Mme. A. Weber-van Bosse, Ann. Jardin Bot. Buitenzorg, xv, pp. 243–401, pl. xx–xxiv.—In a short introduction the author gives a summary of what is known regarding the cell structure with notes as to the probable fructification of the species of this large and peculiar genus, for, in spite of their abundance and wide distribution in all warm seas, no one has as yet succeeded in detecting with certainty their method of reproduction. The monograph is essentially a systematic study of the species for which the author is especially well qualified, since her excursions to the tropics have given her abundant opportunity for observing the Caulerpae in a living condition, while, on the other hand, she has been able to examine the dried specimens of practically all of the large algological herbaria. The subdivisions of the genus adopted are those of Prof. J. G. Agardh, but the number of species recognized by Mme. Weber is considerably smaller than in other works on the genus. In thus uniting the older described species the author, we think, has shown good judgment, and her excellent presentation of the subject gives a much better view of the genus

as a whole than has been possible to obtain hitherto. Especially in her treatment of the Thuyoideae and Claviferae is the author to be commended. One is at first struck by the very large number of species reduced to synonyms under such species as *C. cupressoides* and *C. racemosa*, which latter name replaces *C. clavifera* as generally used hitherto. But one who has had the opportunity of examining large sets of specimens can hardly fail to approve the specific limitations adopted by the author, for not only are the species themselves very variable but, also, one more than suspects that many of the species previously described owed their assumed characters to some accident of preparation. The arrangement of the present monograph seems to us to be the natural one and one which is likely to be generally adopted.

W. G. F.

11. *De dispositione Delesseriearum;* by Prof. J. G. AGARDH, pp. 239, 8°, Lund, 1898.—This volume, which forms the third part of the third volume of the classic *Species Genera et Ordines Algarum,* of which the first volume appeared in 1848, is a rare illustration of continued scientific activity in a field in which the writer has been a master for more than sixty years. To American algologists it is of special interest, as it includes a revision of the species of Nitophyllum, Delesseria and related genera from our Pacific coast which were originally described in Agardh's Epicrisis and subsequent memoirs, to which are added *Nitophyllum macroglossum*, *N. stenoglossum*, *N. marginatum*, *N. Farlowianum*, *Neuroglossum lobuliferum.* The new genus Erythroglossum with five species includes *Delesseria Woodii* and *D. Californica*, and *Apoglossum* includes *D. dicipiens*, all three Californian species. The new genus Calloseris is founded on a single species, *C. Halliae*, from Florida. W. G. F.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The spring meeting of the National Academy was held in Washington from April 18 to 20. The following gentlemen were elected members: Charles E. Beecher of New Haven; George C. Comstock of Madison; Theodore W. Richards of Cambridge; Edgar F. Smith of Philadelphia; Edmund B. Wilson of New York. The list of papers accepted for reading is as follows:

W. K. BROOKS and CASWELL GRAVE: Ophiura Brevispina.

A. HALL: The shadow of a planet.

A. AGASSIZ: On the Tanner deep-sea tow net. On the diamond and gold mines of South Africa.

A. AGASSIZ and A. G. MAYER: On the Acalephs of the East Coast of the United States.

E. C. ANDREWS: On the limestones of Fiji.

W. McM. WOODWORTH: On the Bololo of Fiji and Samoa.

CHAS. D. WALCOTT: Progress in surveying and protection of the U. S. Forest Reserves.

Gifford Pinchot: The work of the Division of Forestry, Department of Agriculture.

H. S. **Pritchett**: The resulting differences between the astronomic and geodetic latitudes and longitudes in the triangulation along the Thirty-ninth Parallel.

A. **Graham Bell**: On the development by selection of supernumerary mammæ in sheep. On kites with radial wings.

S. **Newcomb**: Remarks on the Work of the Nautical Almanac Office during the years 1877–98 in the field of Theoretical Astronomy.

W. K. **Brooks** and L. E. **Griffin**: Exhibition of specimens of *Nautilus pompilius*.

The third memoir of volume viii of the Memoirs of the Academy has recently been issued. The title of the paper is: General perturbations of Minerva (93), by Jupiter, including terms only of the first order with respect to the mass, together with a correction of the elements, by W. S. Eichelberger, Ph.D.

2. *Annual Report of the Board of Regents of the Smithsonian Institution, to July, 1897;* pp. xlvii, 686. Washington, 1898.—The Report of the U. S. Natural History Museum, under the direction of the Smithsonian Institution, for 1896, was noticed in the last number, and we have now issued the Smithsonian Report for 1897. The early portion of this is devoted to an account of administrative matters, by the Secretary, Professor S. P. Langley. This occupies some eighty pages. The remainder of the volume, or General Appendix, contains reprints of a well-selected series of papers on a very wide range of subjects; these include memoirs on astronomy, physics (X-rays, etc.), chemistry and so on through to archæology. The volume closes with an obituary notice of George Brown Goode by S. P. Langley, and one of Francis Amasa Walker by G. F. Hoar and C. D. Wright.

3. *Harper's Scientific Series.*—The recent additions to the series of Harper's scientific memoirs include Volume III, on *Röntgen Rays*, edited by Professor **George F. Barker** of Philadelphia, and Volume IV, on the *Modern Theory of Solution*, edited by Dr. **Harry C. Jones** of Johns Hopkins University. The first of these contains the original paper by Röntgen, and also others by Stokes and J. J. Thomson. Each of the papers is followed by a biographical sketch of the author, and the bibliography of the subject is added at the end. This subject is one of very great interest at the present time, and indeed this statement may also be made about Volume IV on the Theory of Solution. This latter contains papers by Pfeffer, Van 't Hoff, Arrhenius, and Raoult, with the usual useful editorial matter.

OBITUARY.

Dr. **Gustav Wiedemann**, the distinguished physicist, for twenty-two years (1877–1899) editor of the Annalen der Physik und Chemie, died on March 23 at the age of seventy-three.

O C Marsh

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

OTHNIEL CHARLES MARSH.

Among the leading men of science in America, Professor Marsh was unquestionably one of the best known, and had one of the strongest personalities. The world-wide reputation he enjoyed, however, is not altogether attributable to the particular department of research in which he stood without a peer, for, added to his attainments in Vertebrate Paleontology, he possessed an unusual number of mental qualifications in other lines, as well as marked personal characteristics which made him known and felt where his science could never reach. His fame will undoubtedly rest on his work among the Fossil Vertebrates. Nevertheless, his energy and attainments in other directions were sufficient to have made for him a permanent record.

The nearness of the perspective at the present time renders it difficult properly to individualize and accord the true rank to the many important discoveries Marsh has made. He brought forth in such rapid succession so many astonishing things that the unexpected became the rule. The science of Vertebrate Paleontology could not assimilate new material so fast, and it will be years before the true significance and bearing of much that he has done will be understood. The constant stream of vertebrate riches which, from 1868 to 1899, flowed into the Yale University Museum from the Rocky Mountain region had a similar bewildering effect on Marsh, for it was impossible for him to do more than seize on what appealed to him as the most salient. The work of the hour was to him of prime importance, whether it was for the determination of a new order of mammals or a new cusp on a tooth. Still, he seems to have had a just conception of relative values, for it will be found that he plucked the most luscious plums from the paleontological tree, and left chiefly the smaller or unripe and imperfect fruit untouched.

Another element in his success was seen in the improvement he made in the methods of collecting, preserving, and developing vertebrate fossils, so that even forms long known only from fragmentary remains were represented in his collections by almost complete specimens, presenting nearly the same degree of novelty shown in forms actually new.

In illustration of this, the Brontotheridæ, Ceratopsia, and the Mosasauria furnish excellent examples. Prout, in 1846, described, as *Palæotherium*, the fragment of a lower jaw from the Miocene of Nebraska, but Marsh first showed the affinities and range of forms in the group, through his splendid restoration of *Brontops* and the description of a number of allied types from nearly perfect material. Cope, in 1875, figured some pieces of bone of unknown relationships, which long remained in the paleontological scrap-basket.* Marsh, by his descriptions of the marvelous series of genera and species belonging to the Ceratopsia, demonstrated what these reptiles really were, and gave to science a nearly complete knowledge of one of the most bizarre monsters known. The first Mosasaur was obtained in Holland previous to 1785. It remained imperfectly known for nearly a century, when Marsh, by his contributions to its anatomy, made possible a clear understanding of its structure and affinities. In the same way it could be shown that to many old descriptions of genera and species based upon single teeth, he was enabled to add a knowledge of the remainder of the animal. Not only did he thus contribute the missing information in regard to many previously described forms, but he brought out a host of entirely new types, and made his science one of the most complete exponents of the doctrine of evolution.

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* *Polyonax.*

As a collector, Marsh was seen at his best, and the collections he amassed during his forty-five years and more of activity in this direction form a lasting monument to his perseverance and foresight. A person with means and inclination may be supposed to have the necessary qualities for accomplishing his aims, whether they are first editions, autographs, or fossils, but had Marsh possessed no further qualifications than these, the results of his collecting would fall far short of what he really attained. He not only had the means and the inclination, but entered every field of acquisition with the dominating ambition to obtain everything there was in it, and leave not a single scrap behind. Every avenue of approach was made use of, and cost was often a secondary consideration. The nine-tenths, when attained, were only an additional stimulus for securing the remaining one-tenth. Of course, this ideal of completeness was often impossible of accomplishment, and yet it served to bring to the Yale University Museum collections which are unique from their richness and extent.

In making an estimate of his character, it must not be forgotten that he developed wholly without the influence of family and home ties, which in most men profoundly mark their mature life. Self-reliance is probably the strongest trait fostered by the absence of immediate family connections. This, Marsh possessed to an extraordinary degree, and it naturally led to a self-centering of his life and ambitions. Out of it came, also, an absence of the complete exchange of confidence which normally exists between intimate friends. Even where perfect confidence existed, he seldom revealed more about any particular matter than seemed to him necessary or than the circumstances really demanded. As a friend, he was kind, loyal, and generous. As a patron of science, he has seldom been equaled. Honest work in any department appealed to him strongly, and he was ever ready with aid and counsel, even at the expense of a personal sacrifice. His disposition was a most happy one, and he was always keenly appreciative of the humorous and ludicrous and fond of relating amusing experiences and anecdotes. The sunny side of his character was nearly always uppermost, and the consideration of subjects of the greatest gravity was enlivened by constant sparkles of wit from his exhaustless store.

He was normally restive under restraint, and met all opposition with power and fearlessness. Having practically created the modern science of Vertebrate Paleontology in America, he resented any encroachment upon the particular fields of research in which he was engaged. This attitude frequently developed feelings of hostility in other investigators, and often alienated him from co-workers in his department of science. Nevertheless, he labored faithfully for the truth as revealed in his work, and was ready to change opinions and published statements whenever facts seemed to warrant it.

His esthetic sense was highly developed, and could be seen in the artistic care he bestowed upon his publications, but more especially on his home. His grounds are a model of landscape gardening. He delighted in his collections of modern paintings, the cultivation of orchids, and above all in the subtleties of Japanese art.

The world was not slow to recognize his contributions to knowledge, for during his lifetime he received a large number of tangible evidences of distinguished consideration in the way of academic and scientific honors, medals, and membership in learned societies.

In 1886, he received the degree of Doctor of Laws from Harvard University, and in the same year the honorary degree of Doctor of Philosophy from the University of Heidelberg. He occupied the chair of Paleontology in Yale University from 1866 to the time of his death. He was Vertebrate Paleontologist to the United States Geological Survey, and Honorary Curator of Vertebrate Paleontology in the United States National Museum.

He was President of the American Association for the Advancement of Science in 1878, and of the National Academy of Sciences from 1883 to 1895. As a presiding officer in the National Academy, he exercised the same amount of care that he bestowed upon his private affairs, and was an active and efficient leader.

In 1877, he was the recipient of the first Bigsby Medal awarded by the Geological Society of London, in recognition of his important labors on the Vertebrate Paleontology of the western territories of the United States. In 1898, the highly valued Cuvier Prize was given him by the French Academy, as one of the most able continuators of the science of which Cuvier had laid the foundations.

Prominent among the various societies of which he was a member may be mentioned:

The National Academy of Sciences; Institute of France; Royal Academy of Sciences, Brussels; Royal Bavarian Academy of Sciences, Munich; Royal Academy of Sciences, Bologna; Royal Danish Academy of Sciences, Copenhagen; Royal Irish Academy; Geological Society of London; Geological Society of Germany; American Philosophical Society; Academy of Natural Sciences, Philadelphia; Zoological Society of London; Société Impériale des Naturalistes, Moscow; Geological Society of America, etc., etc.

Few men have contributed more to THE AMERICAN JOURNAL OF SCIENCE than Professor Marsh. Nearly all his discoveries in science were first announced here, and it is the storehouse of most of his best work.

The subject of the present sketch was born near Lockport, New York, October 29, 1831. His parents were Caleb and Mary Peabody Marsh, formerly of Danvers (now Peabody), Massachusetts. His early education was obtained in the schools of Lockport and at the Wilson Collegiate Institute, Wilson, New York. A residence in a region rich in minerals and fossils is apt to attract the attention of a youth possessing healthy intelligence, and young Marsh soon shared his vacation time between the normal pursuits of shooting and fishing and the more unusual vocation of collecting minerals and fossils. By the time he was nineteen years old, he had thus acquired the taste for scientific subjects which was destined to grow and dominate the remainder of his life.

In 1851, he entered Phillips Academy at Andover, Massachusetts, and continued his studies there until graduation in

1856. He immediately entered the freshman class in Yale College, pursuing the regular classical course, and receiving the degree of B.A. in 1860. Graduate courses in the natural sciences were continued in the Sheffield Scientific School during the two years following (1861–62). The long summer vacations from 1851 to 1862 were occupied in collecting minerals and fossils from New York, New England, and Nova Scotia. To the latter region he made five trips during this interval, and obtained much valuable experience and scientific material. On his second visit (1855) he found some fossil vertebræ in the Coal Measures at South Joggins, representing a new and important vertebrate animal (*Eosaurus*). This discovery finally directed his studies into the channel which became his life-work. At this time, however, his interests were about equally divided between invertebrate paleontology and mineralogy, and it is worthy of note that his first scientific paper was published in THIS JOURNAL in 1861, under the title "The Gold of Nova Scotia."

The description of *Eosaurus* did not appear until 1862, seven years after its discovery. Even then it cannot be said that he had developed a strong liking for vertebrate paleontology. This closes the account of his student life in American schools.

The next three years were passed in study abroad, in the universities of Berlin, Heidelberg, and Breslau. He attended lectures and took special courses with H. Rose, G. Rose, Ehrenberg, Peters, Rœmer, Grube, and Gœppert. The vacations were occupied, as before, by geological excursions. He visited the most important localities in Europe, and obtained extensive collections. His official connection with Yale College began by his appointment, in 1866, to the chair of Professor of Paleontology. This title he held in high esteem, as it was the first established either in this country or elsewhere.

After attending the meeting of the American Association for the Advancement of Science at Chicago, in 1868, Marsh went as far west as Nebraska and Wyoming, along the route of the Union Pacific railroad, then just opened. This trip gave him a foretaste of the inexhaustible fossil riches of the

Rocky Mountain regions, and thenceforth his energies were mainly devoted to their exploration. Scientific expeditions to the western country were undertakings of considerable magnitude in those early days. There was but one railroad in the United States across a region measuring fifteen hundred miles square. White settlements were sparse and remote. Most of the country was unmapped, and with the exception of a few transcontinental trails, almost the whole western half of the continent, save the regions bordering the Pacific, was a boundless expanse of unknown arid plains, mountains, and valleys. Added to these conditions were the indigenous tribes of war-loving Indians, hostile to the whites. Under such circumstances, travel was slow, difficult, and dangerous. It was necessary to have an escort of soldiers and guides, experienced in western life and Indian warfare.

The first Yale Scientific Expedition was organized and engineered by Marsh in 1870. The party consisted of thirteen persons besides the officers and men of the military detachments who escorted them from various military posts along the route.* They explored the Pliocene deposits of Nebraska and the Miocene of northern Colorado, then crossing into Wyoming they made collections in the Eocene (Bridger Basin), and passing south discovered a new Eocene basin in Utah (Uinta Basin). At each of these places many important finds were made. The party next visited California, where minor collections were obtained from the Pliocene. Returning, they spent some time exploring the Cretaceous beds of western Kansas, so rich in the remains of aquatic reptiles, and now famous for having furnished the first toothed birds and American toothless flying reptiles.

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*Members of the Yale party were O. C. Marsh, C. T. Ballard, C. W. Betts, A. H. Ewing, G. B. Grinnell, J. W. Griswold, J. R. Nicholson, C. McC. Reeve, J. M. Russell, H. B. Sargent, J. W. Wadsworth, E. Whitney, Jr., and H. D. Ziegler. The escorts consisted of:—

From Fort McPherson, Nebraska.—Commanding officer, Gen. Eugene A. Carr. Lieuts. Bernard Reilly, Jr., and Earl D. Thomas, in command of escort, 5th Cavalry; Buffalo Bill and Major Frank North, guides; and two Pawnee Indian scouts ("Lahurasoc" and "Tuckatelous").

From Fort D. A. Russell, Wyoming.—Commanding officer, Gen John H. King. Capt. Robert H. Montgomery and Lieut James McB. Stembel, in command of escort, 5th Cavalry.

From Fort Bridger, Wyoming.—Commanding officer, Major R. S. LaMotte. Lieut. W. N. Wann, in command of escort, 13th Infantry: Mexican guide ("Joe Talemans").

From Fort Wallace, Kansas—Commanding officer, Gen. Henry C. Bankhead. Ed. Lane, guide; Lieut. Charles Braden, in command of rescue troop.

The second, third, and fourth Yale Scientific Expeditions (1871, 1872, 1873) were modeled after the first. New regions in the West were visited, and extensive series of remains of extinct animals were obtained. Coincident with these discoveries, Marsh published frequent scientific papers describing and illustrating the more important forms, and paleontological literature was enriched by the addition of more startling and wonderful types of animal life than had been hitherto known from the rest of the world.

Owing to Indian outbreaks and a general uneasiness in the West, no regular expedition was organized in 1875. Late in the fall, however, Marsh went to the Bad Lands of Nebraska and Dakota accompanied by an escort from Fort Laramie to the Red Cloud Agency. The consent of the Indians was deemed necessary to search for fossil bones in their country. A treaty was obtained with difficulty and then assistance was withheld. Nevertheless, with great hardship owing to extreme cold, the party succeeded in reaching the desired region, and made important discoveries, among which numerous remains of the gigantic Brontotheridæ are the most noteworthy.

It was at this time that he became aware of the frauds practiced upon the Indians by the agents of the Government, and the way the Government was in turn defrauded through their misrepresentations. He promised Red Cloud to bring the matter before the President for redress. This was done with signal success, resulting in the complete routing of the Indian Ring, and the downfall of the Secretary of the Interior as well as in his political death.

The rapid settlement and development of the West rendered it no longer necessary to fit out expensive expeditions, especially as many of the localities were easily accessible by railroad. Therefore, after 1876, local collectors and small parties were employed in continuing the work of collecting fossils so successfully begun by the Yale Scientific Expeditions. Nearly every season, however, Marsh visited the localities where work was being carried on, and some time each year was spent in reconnaissance for new fields of labor.

The right wing of the Peabody Museum was completed in 1875, the means having been furnished by Mr. George Peabody largely through the influence of his nephew, Professor Marsh. It was to his uncle, also, that Marsh was indebted for his educational advantages and for his private fortune. The old Yale Cabinet had long been outgrown. The rooms became so crowded that for years there was only space for a chalk line dividing the different departments. The collections which had been accumulating during so many previous years found a commodious home in the new museum, and work was resumed with great activity under more favorable conditions than heretofore. Huxley's visit in the following year was a further stimulus to higher work, as is clearly evinced in the celebrated Nashville address mentioned elsewhere.

The National Government had not altogether neglected its opportunities for scientific research in the West during this period, though the results in the way of substantial collections were far inferior to those Marsh had obtained. For some time previous to 1878, there were four separate surveys, two under the Engineer Department of the Army and two others, extensions of private expeditions, under the Department of the Interior. In the reorganization ordered by Congress in 1878, Marsh, as acting President of the National Academy of Sciences, was the chief instrument in effecting a consolidation and in defining the relations of the present United States Geological Survey with the general Government and with the United States National Museum. The wisdom of this change was at once apparent, and the Survey is now often considered one of the most economical, best managed, and productive departments of the Government.

After repeated solicitation and with promises of material aid in the way of publication and collections, Marsh, in 1882, accepted the appointment of Vertebrate Paleontologist to the United States Geological Survey. This position he held to the time of his death, although the field work for the survey was terminated in 1892. His connection with the Survey gave him increased facilities for publication and for prosecuting explorations in the West. He successively projected the publication of a number of large monographs on various groups of vertebrate fossils. It is a great misfortune that but two of these were ever finished by the author. The monograph of the Odontornithes appeared in 1880, and that of the Dinocerata in 1885. The others were left in various stages of incompleteness at the time of his death. The proposed volumes treated of the Sauropoda, the Brontotheridæ, the Stegosauria, Theropoda, Ornithopoda, Mesozoic Mammals, and the Ceratopsia. Most of the investigations had been completed, a large part of the plates and figures engraved, and preliminary descriptions published, but the philosophical and phylogenetic problems are largely untouched. The loss to science is greatest in the volumes relating to Reptiles, especially the Dinosauria, for in this subject Marsh stood as the sole possessor of an acute and comprehensive knowledge of one of the most wonderful and difficult groups of vertebrates known. He planned his life-work on the basis that immortality is here and not in the hereafter. It seemed difficult for him to realize the limitations of human existence and worldly accomplishment.

In the closing years of his life he had two ruling ambitions,—first, to see the main building of the Museum erected, and, second, the completion of his monographs. The accomplishment of the first is imperative and would permit of the proper care and display of the priceless treasures he has accumulated. The attainment of the second would cancel his obligations to science. Neither was realized.

As one of the trustees of the Peabody Museum and as Curator of the Geological Collections, Marsh performed his chief duties in connection with Yale University. The final transfer to the University, of all the collections he had accumulated, was made January 1st, 1898, and soon after the gift was accepted by the Corporation. These collections are so extensive as to merit particular attention, especially since they represent the most valuable part of the work of a lifetime, and form the chief monument of one of Yale's most noted men. As expressed in the deed of gift, the collections comprise:

1. The Collection of Vertebrate Fossils. This is the most important and valuable of all. It is very extensive and contains a large number of type specimens, many of them unique, and is widely known from the descriptions already published. In extinct Mammals, Birds, and Reptiles, of North America, this series stands preëminent. The collection was pronounced by Huxley, who examined it with care in 1876, to be surpassed by no other in the world; and Darwin, in 1878, expressed a strong desire to visit America for the sole purpose of seeing it. Since then it has been more than doubled in size and value, and still holds first rank. The bulk of this collection was secured in western explorations, which were extended over a period of nearly thirty years.

2. The Collection of Fossil Footprints. These specimens are mainly from the Connecticut Valley, and thus have a special local interest.

3. The Collection of Invertebrate Fossils. This includes a large amount of interesting material from many formations and localities, both in this country and in Europe. Among the series of specimens especially valuable may be mentioned several thousand from the famous Mazon Creek locality in Illinois; a very extensive collection of Crinoids from Crawfordsville, in Indiana; the largest collection of nearly entire Trilobites yet discovered; and one of the rarest series of Silurian Sponges known, including important type specimens.

4. The Collection of Recent Osteology. This is believed to be one of the most complete collections in this country for purposes of study. Special efforts have been made for many years to secure the skeletons of rare existing vertebrates from every part of the world, particularly of Mammals, Birds, and Reptiles. The collection is especially rich in Anthropoid Apes.

5. The Collection of American Archeology and Ethnology. This collection is replete in Central American antiquities, comprising several thousand, many of them unique. Among others is the famous deZeltner collection from the same region, containing a number of gold ornaments. The specimens from Mexico are also of great interest, and the series is a representative one. It includes the well-known Skilton collection.

6. The Collection of Minerals. This is a limited collection, but contains many valuable specimens, among them probably the most interesting series known of Nova-Scotian Zeolites. These were mainly collected by Marsh, before he was graduated at Yale, during six expeditions to Nova Scotia.

Besides the six main collections named, there are several others of less value, which include fossil plants, casts of fossils, geological specimens, and recent zoological material.

To these should be added the results of his last work in endeavoring to increase the scope of the material in the Peabody Museum. For many years it was his desire to secure a collection of fossil Cycads, and when the opportunity offered, he embraced it with characteristic vigor, so that within the last year and a half the Museum has received an amount of material which in importance and quantity is second to none.

From their extensive and varied nature, these collections thus presented to the University will long afford abundant material for original investigations, and will ever attract to New Haven specialists in Paleontology and Archeology.

Professor Marsh's life was remarkably free from the petty annoyances of poor health which so often interfere with human comfort and ambitions. In the midst of his scientific work and while making plans for the growth of the Museum, he was suddenly overtaken by the malady which resulted in his death. He died of pneumonia, on March 18th, 1899, in his sixty-eighth year, after an illness of about a week. His work as an investigator in natural science, his wonderful scientific collections, and his munificence to Yale, are his legacies to the higher education of mankind.

Although Marsh was an ardent collector in Archeology, he published very little on this subject, and his paper (1866) on an Ancient Sepulchral Mound near Newark, Ohio, is practically the only one. His three mineralogical papers, published between 1861 and 1867, show the results of considerable labor and careful investigation. They treat of the Gold of Nova Scotia, a Zeolite mineral from the same region, and a catalogue of the mineral localities of the maritime provinces of Canada.

In the field of Invertebrate Paleontology, he likewise was an indefatigable accumulator of material, though after 1869 he published nothing in this department. Two papers presented some Annelids considered as new, from the Jurassic of Germany. Another showed the origin of the double lobe-lines in *Ceratites*. His papers on American invertebrates comprised a description of a new genus of Fossil Sponge (*Brachiospongia*), a new form of Crustacean Trail from the Potsdam Sandstone, and a note on color markings in *Endoceras*. He also showed that *Palæotrochis* and *Lignilites* were not of organic origin, though the contrary had been previously supposed.

In the domain of Geology, his chief interests lay in the formations from which he secured important series of fossil vertebrates. Probably his greatest geological discovery was the Uinta Basin, an Eocene deposit of the eastern Uinta Mountains. It was first visited in 1870. Having studied most of the Tertiary lake basins in the Rocky Mountain region, he gave, in 1875, a synopsis of their geological features. As a natural result of studying Geology in Germany, he was much impressed with the methods of marking the separate horizons by means of some characteristic fossil. He believed the vertebrates were the most sensitive time-markers, and therefore endeavored to determine and limit geological horizons wholly by fossil vertebrate remains. The inherent fault of this system is that the vertebrates are not always the most highly differentiated and specialized types in any given fauna, and it is these qualities alone that can be safely employed in organic chronometry. This method is usually of great value in fresh-water deposits rich in vertebrate remains, but it can be seldom used to advantage in marine sediments or in formations containing a scanty vertebrate fauna. Thus, while the name Equus Beds is very appropriate for a horizon in the Pliocene, on account of the abundance of remains of fossil horses, the same cannot be said of the term Eosaurus Beds as an equivalent of the entire series of the Coal Measures, especially as but two vertebræ of this animal have ever been discovered. Geological facts will be found scattered through many of his publications dealing principally with fossil vertebrates. One of the latest problems to interest him was the age of the series of variegated clays extending from Martha's Vineyard south along the Atlantic coast into Maryland. His investigations led him to refer them to the Jurassic, a formation which had been considered as absent in eastern North America.

There yet remains for consideration the real work of his life,—his publications on the Fossil Vertebrates, and it is at once evident, from a glance at the bibliography, that his chief researches were upon the Reptiles, Birds, and Mammals. There are three papers on Fossil Fishes, containing notices of several new forms, but no real research in this class was ever undertaken by him. The Amphibians also claimed but little attention, and his observations on the metamorphosis of the recent *Siredon* into *Amblystoma*, and two brief notices of amphibian footprints in the Devonian and Carboniferous, comprise the whole.

It is with extreme hesitation and a sense of inadequacy that the writer ventures to review, even in the briefest and most superficial manner, the work which undoubtedly constitutes the literary essence of his life-work. Future investigators alone can critically estimate the great mass of facts which Marsh brought out and which he wove into the departments of fossil Reptiles, Birds, and Mammals.

His most comprehensive work, and in many ways the most masterly, is the address delivered before the American Association for the Advancement of Science, at Nashville, in 1877. In this paper, entitled the "Introduction and Succession of Vertebrate Life in America," he traced the introduction of the various types of vertebrate life then known in America, beginning with the lowest fishes and ending with man. The amount of knowledge on the lower classes of vertebrates, including the reptiles, was then too meager to enable him to give more than occasional hints as to their phylogeny. But his handling of the Mammalia showed the clearest insight into the development and affinities of many of the important types, and marked him as a true philosopher.

A glance at the modern text-books of Geology and Paleontology reveals how much America has done for the fossil vertebrates in the three classes of Reptiles, Birds, and Mammals. It will also show that Marsh contributed more than any other investigator toward the prominence now accorded to the American forms.

His work on the Reptilia is not equally divided among the various orders, for the Dinosauria claimed his attention above all others. To this group he lent his best efforts, and he compassed it so thoroughly as to be its sole master. It seems only necessary in this place to notice the complete restorations he made of some of these remarkable animals. In this list are included *Anchisaurus*, *Brontosaurus*, *Laosaurus*, *Ceratosaurus*, *Camptosaurus*, *Stegosaurus*, *Triceratops*, and *Claosaurus*. It must be remembered that nearly all these animals were of gigantic stature, some of them the largest land animals yet known, and also that each restoration represents a number of separate investigations on the structure of the skull, the limbs, the vertebræ, the pelvis, etc. In most cases, only by this means was it possible to bring together gradually, part by part, until the sum of the knowledge warranted a complete representation of the skeleton. The material of many of the genera he described is still in these various stages of progress, awaiting new additions of portions yet unknown in order to form a finished conception of the entire animal. His extensive report on the Dinosaurs of North America, published in 1896, gave a synopsis of what he had accomplished up to that time, but as remarked elsewhere their philosophical treatment he had reserved for his final monographs.

Probably, among the Reptilia, next in importance to his work on the Dinosauria is that on the Mosasaurs. In this he first announced the discovery of the dermal armor, the position of the quadrate, the finding of the stapes, the columella, the hyoid, the sclerotic plates, the quadrato-parietal arch, the malar arch, the transverse bone, the pterygoids, the pterotic bone, the sternum, the anterior limbs, the posterior limbs, the length of the neck, and details of the pelvic region. Thus he contributed a knowledge of some of the most essential characters of the skeleton in this group. In other groups of aquatic reptiles, he also brought out new genera and types of structure. Prominent among these may be mentioned *Baptanodon*, a toothless Ichthyosaurian. Marsh was the first to describe the remains of fossil serpents in the western Tertiary deposits, and likewise the first to discover the remains of flying reptiles in America. The latter were of unusually large size and remarkable for the absence of teeth.

The acquisition of a unique specimen of Pterodactyl from the lithographic slates of Bavaria enabled him to supply the long sought information regarding the wing and caudal membranes. Notices of a number of new species of fossil Crocodiles, Lizards, and Turtles, complete this survey of his work on the Reptilia.

Practically, most of the present knowledge of extinct bird-life in America is contained in Marsh's publications, which include descriptions of numerous species, ranging from the Jurassic to the Post-Pliocene. Unquestionably, the one discovery which is always foremost in men's minds in a consideration of his work is the determination of an extinct order of birds possessed with teeth. The study of the Dinosaurs and Toothed Birds showed that one by one characters considered as avian were likewise present in reptiles, and that many reptilian characters were present in these primitive birds; so that at the end there did not seem much else besides feathers to distinguish them. Marsh's investigation of fossil birds led to the publication, in 1880, of his first monograph, "Odontornithes: a Monograph on the Extinct Toothed Birds of North America." In this volume, he carefully figured and described all the known types, and presented complete restorations of the two leading genera, *Hesperornis* and *Ichthyornis*. He concluded that birds most nearly resemble some of the small Dinosaurs from the American Jurassic, and that both classes originated at least as far back as the Trias or late Paleozoic, in some sauropsid type.

A discovery which rivaled that of the Toothed Birds, although not so wholly his, was the genealogy of the Horse. Huxley and Kovalevski traced the equine branch through the Pliocene to the Upper Miocene in Europe, but the true and remote ancestry remained unsolved until the American types were described by Marsh. He showed that a primitive and diminutive polydactyl horse existed in the Lower Eocene, and that from this type, by gradual and progressive change through successive horizons of the Eocene, Miocene and Pliocene, there had been evolved all the intermediate stages leading to the modern horse.

Next in importance and interest should be noticed the series of papers culminating in the monograph of the Dinocerata, issued in 1886 by the United States Geological Survey. His work in other groups of mammals is scattered through a large number of separate papers, and contributions were made to every known order. The Tillodontia comprise one of the most remarkable of the types. Among others are the first remains of fossil Primates, Cheiroptera, and Marsupialia, known from North America. The Brontotheridæ and Coryphodontia received considerable attention. A monograph had been begun on the former, and restorations of a typical genus of each were published.

One general conclusion of much significance was the outcome of his researches on the Mammals. It was that the Tertiary genera possessed very small brains. As a single example, *Dinoceras* may be taken. This animal was but little inferior to the elephant in bulk, but its brain capacity was not more than one-eighth that of existing rhinoceroses.

The first Mesozoic Mammal in America was described by Emmons, in 1857, from the Triassic of North Carolina. Marsh, by his extensive discoveries, was enabled to fill up the gaps to the Tertiary with many genera and species from the western Jurassic and Cretaceous. Probably nine-tenths of all the Mesozoic Mammals known in the world were described by him, and while these remains are of great interest, yet from their fragmentary condition they are not of the highest scientific value, because little is known beyond the jaws and a few limb bones.

In closing the outline of the discoveries made by this investigator, one cannot help being impressed with their signal brilliancy, their great number, and especially by their unique importance in the field of organic evolution. Were all other evidence lost or wanting, the law of evolution would still have a firm foundation in incontrovertible fact. The study of variation and embryology in recent animals gives hints as to the truth, but Paleontology alone can give the facts of descent.

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ART. XLVI.—*The Camden Chert of Tennessee and its Lower Oriskany Fauna;* by JAMES M. SAFFORD and CHARLES SCHUCHERT.*

Part I. The Camden Chert.

By JAMES M. SAFFORD, State Geologist.

IN March, 1855, the writer discovered in Benton County, Tennessee, at several points, excellent outcrops of Lower Helderberg shales and limestones, very rich in fossils. The discovery was important, since it settled the question as to the presence of the Lower Helderberg, as a distinct formation, in Tennessee, west of the meridian of Nashville. In subsequent years, this discovery also led to a recognition of the chert now referred to as Oriskany, which I have designated the Camden chert for the reason that at Camden, the county-seat of Benton, is seen one of its best exposures.

One of the localities discovered in Benton County was a bluff on Big Sandy River, about five miles from its mouth, at a point then in Henry County, and known as the old William's Mill Site. This locality is referred to in "Geology of Tennessee," 1869. As stated on page 325 of that book, there are here exposed about 50 feet of bluish limestone, mostly shaly. Above this and running back on a slope from the precipitous portion of the exposure, "are loose, angular, flinty masses, containing the fossils of the rocks below, and derived from cherty layers not seen." The fossils in the chert were not numerous nor in good condition, but what was seen of them led, at the time, to the conclusion stated.

In 1884, I recognized the chert at Camden as a distinct formation. I had, in passing through the country, seen this horizon and had referred it without special examination to the "Silicious Group" (Lowest of Subcarboniferous), outcrops of which, very like the chert of Camden, are seen at many points in Benton and counties north and south of it. In my excursion of 1884, however, I stopped for some time at Camden to study the formations. The fossils in the chert arrested my attention, and reminded me of those in the flints seen at William's Mill in 1855. But at Camden, the chert was in comparatively great force, at least 60 feet of it being exposed. At first, I was inclined to consider the chert a division of the Lower Helderberg, but subsequent studies of the fossils at home forced me to the conviction that, as a group, they must be Oriskany. The fact that the formation was one of chert also pointed to this.

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Afterwards, in 1885, 1886, and 1887, I visited localities where I thought the Camden might outcrop. One of these is Big Sandy Station, in Benton, on the Memphis branch of the Louisville & Nashville Railroad, and near the point where the road crosses Big Sandy River. Here I found the chert well developed and abounding in fossils. The outcrops are as extensive and as good as at Camden. For several miles south of Big Sandy, the chert appears on the hillsides as loose angular gravel.

Five miles south, on the Lower Camden road, Lower Helderberg limestones are seen cropping out from beneath Camden chert, with Tertiary beds also overlapping all in unconformable contact.

In Henry County the Camden chert outcrops in considerable areas, west and south of the William's Mill locality. It is seen in limited thickness above the Lower Helderberg in Decatur County, and in the same relation, east of the Tennessee River, in Stewart County. In the latter locality, it outcrops in the bluff on the Cumberland River below Cumberland City. The greatest development of it, however, is on the west side of the Tennessee River, in a strip of country lying in Henry, Benton, and Decatur Counties.

In 1897, I called the attention of Mr. Schuchert to the Camden chert, at the same time trusting he might be able to visit the Camden locality. This he did, collecting a series of fossils, which he studied, kindly giving me the results. I am under special obligation to him for this visit.

Part II. The Camden Lower Oriskany.

By Charles Schuchert.

In the spring of 1897, the writer collected for the U. S. National Museum Lower Helderberg fossils in western Tennessee, and while in Nashville, Professor Safford also directed his attention to a lot of Camden chert organisms. Since no strata of Oriskany age had been recorded in Tennessee, the importance of determining the equivalency of the Camden chert with other regions made it desirable to know more of its fauna, and with that object in view, a collection was made at Camden.

The fossils of the Camden chert are, as a rule, natural casts of both the interior and exterior of the organism, and preserve the fined markings in detail. This fauna is closely related to that described by Meek and Worthen* from the "Clear Creek

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* Geol. Surv., III, vols. i, ii, and iii.

Limestone" of southern Illinois, Alexander, Jackson, and Union Counties. From this region are known but 11 species, and 8 of these are also found in Tennessee. They are *Anoplia nucleata*, *Anoplotheca flabellites*, *Eatonia peculiaris*, *Spirifer worthenanus*, *S. hemicyclus*, *Megalanteris condoni*, *Amphigenia curta* and *Strophostylus cancellatus*.

The "Clear Creek limestone" of Illinois is intimately connected with the Lower Helderberg below, and is not less than 200 feet thick, being followed by a "quartzose sandstone" from 40 to 60 feet in thickness. The latter is probably equivalent to the Upper, or typical, Oriskany of New York, and does not appear to be present in western Tennessee. From Professor Safford's description of the Camden chert, it is evident that the Lower Oriskany thins rapidly southward. In Tennessee, it is about 60 feet in thickness, while it is not less than 200 feet thick in Illinois exclusive of the Upper Oriskany, which is entirely absent in the former state.

The "Camden chert" fauna contains 32 species, and 6 of these are restricted to southern Illinois and western Tennessee. Of the entire fauna, 24 species are found either in the Lower Helderberg or in the Lower Oriskany of other regions, and 20 occur in the Upper Oriskany or Corniferous. After removing the 13 species common to both the Lower and Upper Oriskany, and the two restricted forms, 17 remain. Of these 10 occur either in Lower Helderberg of Lower Oriskany rocks of other regions, while 6 are found in higher beds. This evidence, therefore, indicates clearly a Lower Oriskany age for the "Camden chert" of Tennessee and the "Clear Creek limestone" of Illinois, which indication is the more marked because of the absence here of such characteristic Upper Oriskany species as *Hipparionyx proximus*, *Chonostrophia complanata*, *Spirifer arenosus*, *Rensselæria ovoides*, *Meristella lata*, *Camarotœchia pleiopleura*, *C. barrandei*, or *C. speciosus*.

Lower Oriskany fauna of the Camden Chert of Camden, Benton County, Tennessee.

	In Lower Oriskany elsewhere.	In Upper Oriskany elsewhere.
Zaphrentis rœmeri Hall ?	L. H.[*]	
Pholidops terminalis Hall	×	×
Hipparionyx proximus Vanuxem ? A very small specimen if this species	×	×
Chonetes mucronatus Hall ?		×
" melonica Billings	×	×
Chonostrophia reversa (Whitfield)		U. H.

[*] L. H. = Lower Helderberg; U. H. = Upper Helderberg. This list is based on the collection in the U. S. National Museum.

	In Lower Oriskany elsewhere.	In Upper Oriskany elsewhere.
Stropheodonta (Lepstrophia) perplana (Conrad)	×	U. H.
Orthothetes woolworthanus Hall	×	
Anoplia nucleata Hall	×	×
Cyrtina affinis Billings	×	×
Metaplasia pyxidata Hall	×	×
Spirifer hemicyclus Meek and Worthen	×	
" tribulis Hall	×	×
" worthenanus Schuchert	×	
Anoplotheca flabellites (Conrad)	×	×
Meristella lævis (Vanuxem)	×	
" sp. undet.		
Camarotœchia tethys (Billings) ?		U. H.
Atrypa reticularis Linne	×	×
Eatonia pecularis (Conrad)	×	×
Amphigenia curta Meek and Worthen ?	×	
Rensselæria ovoides (Eaton) ?	×	×
Megalanteris condoni (McChesney)	×	
Tentaculites acula Hall	×	×
Avicula cfr. obscura Hall	L. H.	
Actinopteria cfr. textilis Hall	×	
Acrocoulia magnifica (Hall) ?		×
Acrocoulia (Orthonychia) tortuosa (Hall)?	×	×
Diaphorostoma turbinata (Hall)		U. H.
Strophostylus (?) cancellatus Meek and Worthen	×	
Phacops cristata Hall		×
Ostracoda.		
Total 32 species	24	20

Art. XLVII.—*Recent discovery of rocks of the age of the Trenton formation at Akpatok Island, Ungava Bay, Ungava;* by J. F. Whiteaves.

While accompanying the Hudson Bay expedition despatched by the Canadian government in 1897, in the sealing steamer "Diana," Dr. R. Bell, of the Geological Survey of Canada, spent the 13th of September on Akpatok Island, on his way from Ashe Inlet to Fort Chimo. In a preliminary report on his explorations for that year,* Dr. Bell says: "The portion of the island which I saw (from the northern end to the middle of the east side) consists of unaltered gray limestone in horizontal beds, and it presents a perpendicular wall 400 or 500 feet high all along." "This sea-wall is clean-cut and the beds appear thick and solid, but wherever their edges have been long exposed to the weather, or in the hill-sides and ravines of the interior, they split up into thinner layers." "Some fragments observed in one place had the appearance of lithographic stone." "I was enabled to land opposite the place where the Diana anchored, as already mentioned, about the middle of the eastern side, and I improved the opportunity to collect fossils, which, however, were not abundant." "Those obtained indicate the Hudson River formation."

When this last sentence was written, the specimens that it refers to had not been unpacked. Since the publication of the Report from which it and the four preceding sentences are quoted (in May, 1898), these fossils have been examined by the writer, and it at once became obvious, first, that they indicate a little lower geological horizon than the Hudson River formation, viz., that of the Trenton limestone; and, secondly, that they are remarkably similar to the fossils of the Trenton formation of the Red River valley in Manitoba. The collection consists of fifteen species, but two of these are imperfect casts of the interior of shells of gasteropoda, that can only be determined generically. Of the thirteen that remain eleven had previously been found in the Manitoba Trenton, and nine are species that are common at East Selkirk and Lower Fort Garry. The two fossils of which by far the most specimens were collected are *Streptelasma robustum* and *Cyrtoceras Manitobense.* The former is a rather large rugose coral, the types of which are from the Red River valley in Manitoba.

The following is a list of the species represented in the collection, as far as they can be determined.

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* Summary Report of the Geological Survey of Canada for 1897, page 82.

LIST OF FOSSILS FROM THE TRENTON FORMATION AT AKPATOK ISLAND, COLLECTED BY DR. BELL IN 1897.

RECEPTACULITIDÆ.

Receptaculites Oweni Hall.

A very small and worn but fairly characteristic fragment.

ZOANTHARIA.

Streptelasma robustum Whiteaves.

About thirty specimens, of all sizes.

Calapœcia Canadensis Billings.

One specimen.

BRACHIOPODA.

Rafinesquina lata Whiteaves.

One ventral valve.

Leptæna unicostata Meek and Worthen.

A tolerably well preserved ventral valve that is apparently referable to this species.

Plectambonites sericea (Sowerby).

A few specimens.

Orthis tricenaria Conrad.

An unusually large ventral valve.

Orthis (*Dinorthis*) *Meedsi*, var. *arctica* Schuchert.

Three imperfect and badly preserved specimens which Mr. Schuchert thinks look very much like Baffin Land specimens that he is describing under this name.

Orthis (*Hebertella*) *bellarugosa* Conrad.

One good specimen that has been identified with this species by Mr. Schuchert.

Orthis (*Dalmanella*) *testudinaria* Dalman.

A few imperfect specimens.

Platystrophia biforata (Schlotheim).

Two imperfect ventral valves.

? *Rhynchotrema inæquivalvis* (Castelneau).

An imperfect ventral valve, with the cardinal area not visible.

GASTEROPODA.

Trochonema or *Pleurotomaria*. (Species indeterminable.)

A cast of the interior of the last volution and last but one.

Hormotoma. (Species indeterminable, but apparently like *H. Salteri* Ulrich.)

A cast of the interior of three of the volutions.

CEPHALOPODA.

Cyrtoceras Manitobense Whiteaves.

About thirty well preserved but much worn fragments, from less than an inch to nearly two inches in length.

Ottawa, March 23d, 1899.

ART. XLVIII.—*Studies in the Cyperaceæ;* by THEO. HOLM. X. *Fimbristylis* Vahl; an anatomical treatise of North American species. With fourteen figures in text, drawn from nature by the author.

THAT purely floral characters are insufficient for the establishment of genera has been proved by several botanists in recent years. This is especially the case with large orders, where a number of species are to be classified so as to demonstrate, at least, a supposed relationship. It is not uncommon that herbalists content themselves by studying only the floral structure and matching the details with some old illustration or analytical key; but there is, however, more than that to be considered and looked upon, as affinity and relationship. The establishment of natural orders is, of course, a progress, but, to say the least, the genera themselves are often so badly understood and so arranged, that we obtain no more knowledge of the real affinities than if we had followed the system of Linnæus: Monandria, Diandria and so on. It is very common to see species arranged in genera widely apart, on account of the stamens and stigmata being different in number, while the plants otherwise show the same habits and internal structure. Our genus *Fimbristylis* furnishes a good illustration. Merely because some species have two or three stigmata, this genus has been divided into *Dichelostylis* and *Trichelostylis;* and the fact that the base of the style is persistent in some species, but only for some time, has caused the separation of the genera *Isolepis* and *Oncostylis.** Furthermore these genera have been considered as subgenera of *Scirpus* or even as close allies of *Heleocharis*, a consideration, however, that cannot possibly have been based upon observations in the field. But to Bentham and Asa Gray such characters were of less importance, and these authors were liberal enough to include a number of species as true *Fimbristyles*, even if the floral characters did not come exactly within the scope of the original diagnosis or conception of the genus as understood by Vahl. Finally the anatomical study of a number of genera of the *Cyperaceæ* has shown us that certain analogies exist which must be considered as valuable to the study of mutual affinities, promulgated by Schwendener, Palla† and Rikli.

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* It was Martius (Flor. Brasil.) who substituted the generic name *Oncostylis* for *Bulbostylis*, which appears in the Conspectus generum, because DeCandolle had already used *Bulbostylis* to designate a genus of *Compositæ*.

† Palla Ed. Zur Kenntniss der Gattung "Scirpus." (Engler's botan. Jahrbücher, vol. x, Leipzig, 1889, p. 293.)

Considering the genus Fimbristylis in North America not only "sensu strictiori," but including the species which Torrey referred to *Isolepis: stenophylla, ciliatifolia, Warei* and *capillaris* R. et S., we cannot avoid noticing that the general habit of these plants, both annuals and perennials, is very much the same. A dense cespitose growth is characteristic of most of our species; the leaves are generally narrow with short sheaths, and the flowers are arranged in true spikes, either borne on long peduncles constituting open cymes, or sessile in small heads. While a pubescence is rarely observed in *Cyperaceæ*, it is not uncommon in *Fimbristylis*, of which several species have the leaves, stems, involucres and scales clothed with short hairs. In examining the inflorescence, the spikes are mostly, as stated above, arranged in open cymes, where the terminal spike is almost sessile and overtopped by the lateral ones. In *F. castanea* and *F. thermalis* several lateral spikes are borne on long peduncles, but with no further ramifications, representing respectively a di- or pleio-chasium. A similarly constructed cyme is, also, characteristic of *F. laxa* in plants growing in the vicinity of Brookland, D. C.; in specimens from Eustis, subtropical Florida, the lateral inflorescences are, on the other hand, decompound, thus agreeing with *F. spadicea*. The pleiochasium in *F. puberula* is either simple or decompound; in the first case the spikes are considerably larger than in the last, where the spikes consequently are more numerous. The most decompound inflorescence is, however, to be found in *F. autumnalis*, where the secondary branches are pleiochasia, the tertiary, on the contrary, passing over into monochasia of only two spikes, a terminal and a lateral. While in *F. capillaris* the inflorescence is typically a pleiochasium, it is not unusual to meet with specimens where the flowers are reduced to a single spike, at the base of which a long involucral bract is often noticeable, but without supporting any lateral branch. Similar empty involucral leaves, but reduced to scale-like, long-pointed bracts, occur also at the bases of several of the spikes, indicating the place of non-developed inflorescential branches. In species with sessile spikes, *F. Warei* and *F. stenophylla*, the composition of the inflorescence becomes more indistinct, since all the peduncles are very short and the characteristic clado-prophyllon entirely suppressed, a fact that is known also from other genera of *Cyperaceæ* with similarly aggregated spikes: species of *Cyperus, Dichromena, Scirpus, Carex* and others. But where a clado-prophyllon is developed, this is readily noticed at the very base of each lateral peduncle as a tubular sheath, more or less puberulent in our species of *Fimbristylis*. It varies somewhat in shape, being compressed in *F. autumnalis* and its more southern ally *F. complanata*, or bicarinate in *F. castanea* and *F. spadicea*, or it is cylindric as in the other species; the apex is prolonged into two subulate teeth in *F. laxa* and *F. castanea*, but merely slightly oblique in the others. While the inflorescence of *Fimbristylis* does not show any remarkable deviation from that of other *Cyperaceæ*, we have observed in the disposition of the leaves a very peculiar exception from the ordinary rule in this order, at least in some species. As invariably quoted in botanical manuals, the tristichous leaf-arrangement is the characteristic one of the *Cyperaceæ*, while on the contrary the distichous that of the *Gramineæ*. It would hardly be natural to suppose that any such rule should be stable for either of these orders, since exceptions are known if not from the leaves then at least from the arrangement of the spikelets and the inflorescential branches. We might merely call attention to the panicles of a number of *Gramineæ*, of which the branches are not distichous; besides that the spikelets are sometimes spirally arranged, as for instance in species of *Eragrostis*. In the *Cyperaceæ* the distichous arrangement of the flowers with their bracts is well known as the very characteristic of *Cyperus*, *Dulichium*, partly also of *Scleria* and *Dichromena*. But the arrangement of the stem-leaves has, so far, usually been described as tristichous in the *Cyperaceæ*, in spite of the fact that Kunth, in his diagnosis of *F. autumnalis*, characterized the leaves as "distichis," a statement which is absolutely correct. The leaves of this species have laterally compressed sheaths, which soon become split, and the blades are furthermore held in a very peculiar position: with the one margin turned towards the axis or the flower-bearing stem. Although the leaf-blades are not isolateral, they invariably show this position, a fact that we have never noticed before in any of our American species with corresponding anatomical structure excepting in *F. complanata*. The distichous arrangement of the leaves is, however, also to be seen in *F. castanea* and *F. spadicea*, but the leaf-blades are not turned to the side in these species; they occupy the usual position as dorsiventral leaves. Considered from a morphological view-point, it seems strange that such disposition of leaves should be found in a genus like *Fimbristylis*, in which all the other foliar organs, involucral-leaves and floral bracts are arranged in spirals; it would seem more natural to a genus like *Cyperus* or *Dulichium* with the distichous flowers. And by examining the internal structure of such leaves, it seems still more surprising that we find a number of analogies rather than important variations. Furthermore when we compare our North American species with each other, it will be seen from the following pages, that even if they inhabit localities differing greatly in climate and soil, their internal structure does not seem to be influenced to such an extent as to render it impossible to detect several and very gradual transitions. The modern, but often too superficial and hasty classification of plants as Xero- and Hydro-phytes, is not by any means applicable to our genus, at least not to its North American representatives. If such types of plants, Xero- and Hydro-phytes, really exist, it must be proved not by observations in the field alone, but by a very close study of their structural peculiarities. The mere fact that such and such species inhabit dry, sandy places or marshes, ponds, etc., does not necessitate the plants in question to be considered as either xero- or hydro-philous species; their internal structure must be carefully examined before any conclusion can be drawn, as to whether these plants are "solely adapted" to these special environments. As regards our species of *Fimbristylis* it might seem very tempting to classify these in this way: *F. capillaris*, *F. Warei*, *F. stenophylla* and *F. ciliatifolia* as xerophytes, and the remaining species as hydrophytes, but their anatomical structure does not seem to justify any such classification. In order to facilitate the anatomical comparison of the material, which we have examined, it may be well to enumerate the various localities as follows: *F. autumnalis* was collected in wet sandy or clayish soil in the vicinity of Washington, D. C., and in low sandy places near Eustis, subtropical Florida; *F. castanea* was from brackish marshes near the coast of Maryland; *F. spadicea* and *F. puberula* both from wet, sandy soil near Eustis, Florida; *F. laxa* from low meadow-land, rather dry soil, near Brookland, D. C., as well as from low, sandy soil near Eustis, Florida; *F. thermalis* from hot sulphur springs near Golkonda, Nevada; *F. capillaris* from dry, sandy soil near Washington, D. C., and Eustis, Florida; *F. ciliatifolia* from dry, sandy fields in Alabama, and finally *F. stenophylla* and *F. Warei* from dry, sandy soil in the High-Pine-woods near Eustis, Florida. Besides these we have, also examined some specimens of *F. complanata* and *F. capillaris* from Montevideo, Uruguay, which together with a number of other *Cyperaceæ* were presented to the writer through the courtesy of Professor Arechavaleta, Director of the National Museum at Montevideo.

In discussing the anatomy of the vegetative organs of these species, we will begin with

The leaf.

By its greater ability to vary, the leaf appears to illustrate the species better than the stem or root. Considering the mere outline of the leaf, three types are readily distinguished

(1) the relatively broad and flat, as we find it in *F. autumnalis*, *F. thermalis*, *F. spadicea*, *F. puberula*, *F. complanata* and *F. laxa;* (2) the semi-cylindrical in *F. castanea* and (3) the approximately triangular in the remaining species. Very characteristic of the leaves of the first category is the more or less, but always very conspicuous, asymmetric blade, in contradistinction to those of the other species, a fact that has, also, been recorded by Rikli as common to *F. glomerata* (Nees) and *F. paupercula* (Bklr.) In *F. autumnalis* the leaf, as will be seen from the accompanying illustration (fig. 1), is flat and strictly dorsiventral; only the midrib is somewhat projecting on the lower surface of the blade, and this is due to its larger support of stereome. The upper face is perfectly smooth, and there is nothing in the outline to indicate the peculiar position of the blade, as we have mentioned already, being placed edgewise by the twisting of the leaf-sheath. This form of leaf must not be confounded with the sword-shaped leaves of *Iridaceæ*, because both faces are equally well developed in *Fimbristylis autumnalis*, besides in *F. complanata*.

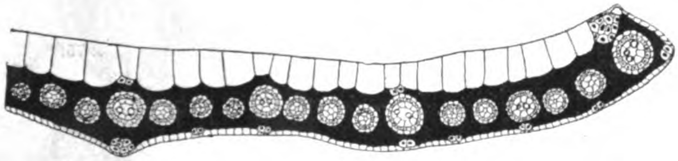

FIG. 1. Transverse section of half of the leaf-blade of *F. autumnalis*. × 75.

The leaf is more likely to be compared with that of a mature *Eucalyptus* or of our evergreen species of *Smilax*, of which the leaves show a similar position. It is strange to see that such peculiar leaf-position is said to be either "a xerophytic character of bog-plants or a natural adaptation of desert-plants." However in these species of *Fimbristylis* the leaf-blade is developed with this position immediately after germination, and we have not noticed any exceptions to this rule in specimens from less dry situations, nor in plants growing in *Sphagnum*-moss. It is a character that seems to be peculiar to these two species, but which cannot possibly be considered as having originated through any means of adaptation, since the structure is identical with that of the other species, in which the ventral leaf-face is turned towards the stem.

While the epidermis of the upper face in *F. autumnalis* consists only of one layer of large, thin-walled cells of equal width all through the blade, we find in *F. complanata* several layers, representing a typical water-storing tissue. Among the other species *F. laxa* (fig. 2) comes nearest to *F. autumnalis*, since the superior epidermis is only composed of one layer, but the leaf is much narrower and the blade is not placed edgewise; furthermore the leaves are tristichous. In *F. spadicea* the accompanying figure (fig. 3) shows that the epidermis has been developed in a few strata, but only in certain places, between the mestome-bundles. It is very strange that this species has often been considered as identical with *F. castanea* or at least as the type, since both are so very different, when considered from an anatomical point of view. By examining the leaf of *F. puberula* (fig. 4) we notice that the upper surface is occupied by a huge mass of colorless and relative large cells, which represent an epidermis of several layers. Besides this the epidermis of the inferior surface is developed as a dense covering of long, unicellular hairs, a fact that would seem to point towards some special adaptation, "a xerophytic character developed in a hydrophilous plant"; yet the species is neither a hydrophyte or xerophyte as these terms are gen-

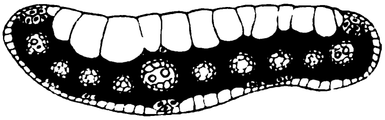

FIG. 2. Transverse section of leaf-blade of *F. laxa*. × 75.

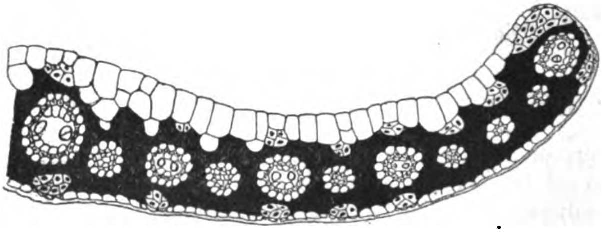

FIG. 3. Transverse section of half of the leaf-blade of *F. spadicea*. × 75.

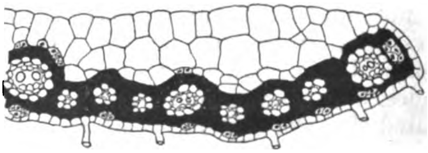

FIG. 4. Transverse section of half of the leaf-blade of *F. puberula*. × 75.

erally applied. A structure similar to that of *F. puberula* but without hairs is to be found in *F. thermalis* (fig. 5), of which the writer received some excellent material from Dr. E. L. Greene. The leaf-blade is here broad and very thick from the immense layers of colorless tissue on the upper surface, the function of which cannot possibly be for the storage of water, since the specimens were growing in hot sulphur springs. *F. castanea* exhibits a very peculiar shape of leaf, this being semi-cylindrical (fig. 6), and of which the upper surface shows a still larger development of colorless tissue than any of the other species we have examined. It was rather surprising to find this narrow leaf developed on a species that inhabits brackish marshes, which are not liable to become dried out during the summer. It is actually the narrowest leaf we have observed in any of the North American species of *Fimbristylis*, in proportion to its length, and the only species that possess approximately as narrow leaves are just those which inhabit a very dry and sandy soil: *F. capillaris*, *F. ciliatifolia*, *F. Warei* and *F. stenophylla*. The accompanying figures (figs. 7, 8 and 9) illustrate transverse sections of leaves from the latter three species, and we notice at once the very narrow, almost triangular outline from the strongly projecting midrib. No large tissue for water-storage is developed in any of these species, but the cells of epidermis are on both surfaces relatively wide, and sometimes a double epidermis may be developed between the mestome-bundles, in both *F. ciliatifolia* and *F. Warei*. Characteristic of the leaf of *F.*

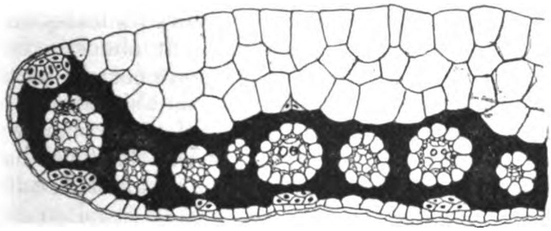

FIG. 5. Transverse section of half of the leaf-blade of *F. thermalis*. × 75.

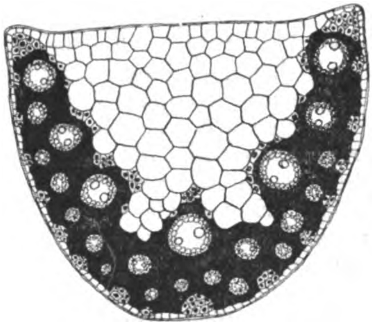

FIG. 6. Transverse section of leaf-blade of *F. castanea*. × 75.

stenophylla (fig. 9) are the double rows of diverging, pointe hairs along the margins and the ribs on the lower surface o the blade.

Although *F. complanata* is not a native of this country, w have examined some specimens, as stated above, from Urugua which were originally labeled *F. autumnalis*, to which it show a very pronounced habitual resemblance. The position of th leaves are exactly the same, distichous with the blade hel edgewise; besides the inflorescence is very rich-flowered. However, while we examined the anatomy we became aware of th fact, that in this respect our plant showed a leaf-structure different from that of *F. autumnalis*, but almost exactly lik that of *F. thermalis*. In order to secure correct identificatio of this South American species, we sent specimens to Mr. C B. Clarke at Kew, who kindly replied that the plant was Link' *F. complanata* var. *Kraussiana*. If Dr. Bœckeler had know of the structural divergencies between this and *F. autumnali* he would hardly have considered them as but one specie even if the outer likeness is very striking.

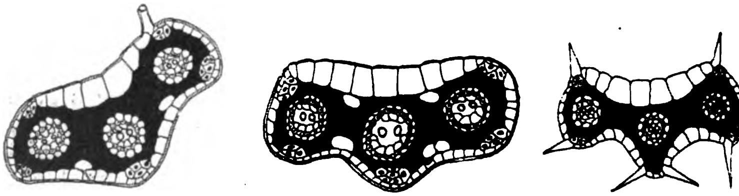

FIG. 7. FIG. 8. FIG. 9.

Leaves of *F. ciliatifolia*, *F. Warei* and *F. stenophylla*; transverse sections. × 75.

If we now compare the leaves, of which we have draw some transverse sections from the middle part of the blade, i is readily seen that the outline and the structure of the uppe epidermis presents certain features for distinguishing th species. Nevertheless these leaves demonstrate several inter gradations, thus the various forms may be easily deducte from one another. The epidermis of the upper surface i either developed as one single layer of large, bulliform cell or as several strata, that cover the mesophyll. None of thes strata are, however, differentiated in such a way as to have th function of opening or closing the leaf, the so-called "Gelenkcellen" of the Germans, common to *Cyperaceæ* and *Gramineæ*

In passing, to describe the minor details of the leaf-structure we observed the cuticle to be very thin and smooth in *F autumnalis*, *F. laxa* and *F. complanata*, less so in *F. spadicea*; in the remaining species the cuticle is very thick, but smooth, not granular. The epidermis of the lower surface is almost smooth with no furrows, and consists usually of smaller cells than that of the upper, and is frequently developed into unicellular hairs or very minute spines, which are directed upwards. The stomata are restricted to the lower epidermis, where they form longitudinal rows outside the mesophyll between the mestome-bundles. Characteristic of the stomata is the deep and somewhat narrow air-chamber, which we have noticed in most of our species with the exception of *F. castanea*, where it is shallow and wide. The guard-cells are projecting in *F. autumnalis*, *F. laxa*, *F. puberula*, *F. spadicea* and *F. complanata*, but not in the other species; they are extremely thick-walled in *F. castanea*.

Similar to all the other *Cyperaceæ*, examined so far, silicious cones are observable in the epidermis-cells that cover the stereome. As regards mechanical support most of our species possess a well-developed stereome, the location of which can be seen on the sections, figured above. It accompanies the larger mestome-bundles as hypodermal groups on the lower surface of the blade, while on the upper it is restricted to the margin. A few thin-walled stereome-cells may be found above some of the largest mestome-bundles, but separated from these by mesophyll. Although the stereome does not form any sheaths around the mestome-bundles, it nevertheless renders a strong support to the leaf by its very thick-walled cells, and is altogether very well represented in our species of *Fimbristylis*, with the only exception of *F. autumnalis* and *F. laxa*, in which it is relatively thin-walled.

The chlorophyll-bearing tissue, the mesophyll, occupies only a small part of the leaf-blade, since it is generally traversed by a number of mestome-bundles, which are especially large in the narrow-leaved species, such as *F. capillaris*, *F. Warei*, etc. It forms a homogeneous tissue on both faces of the leaf, and the cells are true palisades, arranged radially around the mestome-bundles. Furthermore this tissue is very compact in our species excepting in *F. laxa*, of which some specimens from Florida showed wide lacunes; and *F castanea*, in which the palisade-cells are almost star-shaped, leaving numerous and quite large intercellular spaces. Tannin was observed to be very plentiful in this tissue, especially in *F. spadicea*, *F. puberula* and *F. thermalis*.

Considering the mestome-bundles, these are all arranged in a single plane in the leaves of *Fimbristylis;* they vary in proportion to size and outline, the larger being more or less oval, the smaller constantly orbicular. They are imbedded in the mesophyll, and are, as we have seen above, in no connection with the stereome, hence they are "pure" mestome-bundles.

Besides being surrounded by the radially arranged palisade-cells, the mestome-bundles possess, also, a completely closed parenchyma-sheath of small, thin-walled cells, which contain chlorophyll. Inside of this parenchyma-sheath there is a mestome-sheath, thin-walled in *F. autumnalis* and *F. thermalis*, but more or less thickened in the other species. The peculiar "inner chlorophyll-bearing sheath," which we described in a previous article upon *Lipocarpha*,* occurs, also, in *Fimbristylis*, and not only in the genus "sensu strictiori," but also in those American species of *Isolepis* which we have included in the former genus. We found the structure of this sheath to be identical with that of *Lipocarpha*, being composed of much larger cells than the mestome-sheath; also by being closed in the small, orbicular bundles, but interrupted in the larger (fig. 10). The cell-content seems, also, to present the same deep green color as noticeable in *Lipocarpha*.

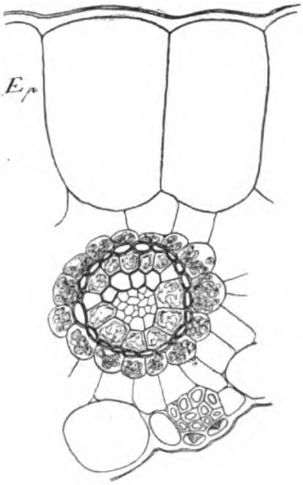

FIG. 10. Transverse section of a mestome-bundle from the leaf of *F. autumnalis*; *Ep.* = epidermis of the upper surface. × 400.

As regards the hadrome and leptome these have, naturally, attained their highest degree of development in the largest mestome-bundles, where these tissues are sometimes separated from each other by one or more layers of thick-walled mestome-parenchyma, as in *F. castanea*, *F. puberula*, *F. spadicea* and *F. complanata*. The presence of the inner, chlorophyll-bearing sheath in our species of *Fimbristylis* will necessarily place the genus as a member of Rikli's "*Chlorocyperaceæ*," among which this author has not, however, enumerated any of the *Isolepis*-species examined by him. Moreover the morphological and anatomical diagnosis of *Isolepis*, as demonstrated by Palla, does not seem comparable with any of the North American plants which by Torrey were referred to this genus. Our species differ very much from *Isolepis* proper by their morphological characters, also by their internal structure. And even if the inner, green sheath is not a constant character to all species in certain large genera such as *Heleocharis* and *Cyperus*, as demonstrated by Rikli, it would not be correct to consider our

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* This Journal, vol. vii, p. 172.

American species as only anatomically distinct from other representatives of *Isolepis*. Our narrow-leaved species of *Fimbristylis* do not show any very important anatomical or morphological characters by which they should be considered as distinct from the others with somewhat broader leaves; they do not present any such divergencies which induced Rikli to separate his *Chlorocyperus* and *Chlorocharis* from *Cyperus* and *Heleocharis*; besides they lack the very conspicuous character: "bractea infima erecta, inflorescentiam quasi lateralem sæpissime excedens, caulem continuans" as pointed out by Bentham.

The stem.

The stem above-ground, which bears the inflorescence at its apex, varies from cylindrical to being almost flattened, but shows, nevertheless, a very uniform structure in our species. The singularly flattened stem of *F. autumnalis* (fig. 11) and *F. complanata* corresponds well with the flat leaves, which are turned edgewise in these species. In *F. castanea*, *F. thermalis*, *F. spadicea* and *F. puberula* the outline is almost cylindrical; in *F. laxa* it is polyedric; in *F. Warei* and *F. stenophylla* the outline is decangular, while *F. capillaris* possesses a penta- or hexa-gonal stem. When compared with the leaf the stem-structure shows many analogies, but the mechanical tissue has here attained a stronger development, the mestome-bundles are arranged in several, more or less concentric, bands and the bark-cells are not arranged radially around the mestome-bundles in all the species.

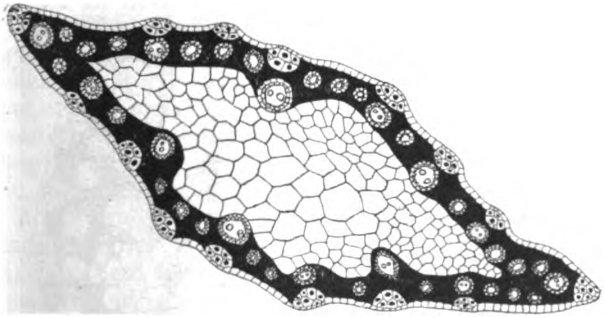

Fig. 11. Transverse section of the stem of *F. autumnalis*. × 60.

While the cuticle of the stem shows the same slight variation as we noticed in the leaves, the epidermis is often more thick-walled and does not develop such dense pubescence as in the leaves. Grooves or furrows are observable in some species, but they are rather shallow and wide; thus the stomata, which are located in these, are freely exposed. We notice the same variation in the relative width of the epidermis-cells as in the leaves; besides the characteristic cones are very numerous outside the hypodermal stereome. The bark-parenchyma forms, similar to the mesophyll, a homogeneous tissue of palisade-cells, which are arranged radially towards the center of the stem in the majority of our species, but not in *F. capillaris*, *F. ciliatifolia*, *F. Warei* and *F. stenophylla*. The bark-parenchyma is commonly quite solid with no lacunes, but the intercellular spaces are numerous and wide in *F. castanea*, *F. thermalis* and *F. puberula*. It is, furthermore, to be pointed out that the bark-palisades, which border on the leptome-side of the innermost mestome-bundles in *F. castanea*, do not radiate towards the center of the stem, but towards the center of the bundle. Cells containing tannin were, also, observed in the stem of various species, but not so abundant as in the leaves. We have stated above, that the stereome is more strongly developed in the stem than in the leaves. This is readily noticed if we compare the leaf-section of *F. castanea*, for instance, with the accompanying figure of a part of its stem (fig. 12). This section shows a number of very large hypodermal stereome-bundles, most of which are situated deep into the bark between the outer band of mestome-bundles. There are, also, a few scattered and very small groups of stereome on the hadrome-side of the innermost bundles. Finally in the pith itself we observed quite a number of stereome-bundles, which were not arranged in any order, and

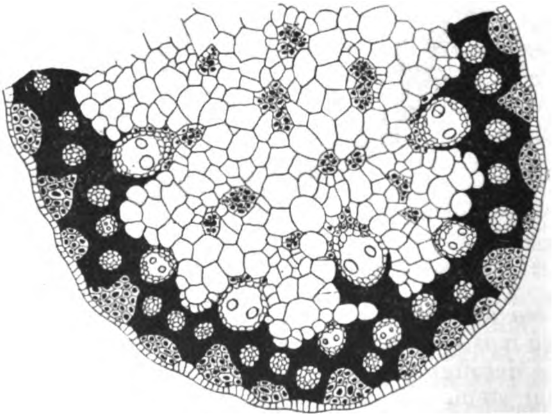

FIG. 12. Transverse section of half of the stem of *F. castanea*. × 75.

of which only a few surrounded minute leptomatic-bundles. Similar stereome-bundles imbedded in the pith were, also, observed in *F. spadicea,* but not in any of the other species, where this tissue is either strictly hypodermal or may be found on the hadrome-side of the innermost mestome-bundles. The largest part of the stem is occupied by a solid pith, mostly consisting of polyedric cells, when considered in transverse sections. With the exception of *F. spadicea*, of which the pith contained much tannin, this matter was not observed in the pith of any of the other species.

In regard to the mestome-bundles these are more numerous in the stem than in the leaf; they may form one single and almost concentric band as in *F. capillaris* (fig. 13), *F. Warei*, *F. ciliatifolia* and *F. stenophylla*, or several as in the other species. They show exactly the same variation as those in the leaves, and the smallest, the orbicular ones, are invariably the most numerous and located near the periphery. Inside of these may be a second band of somewhat larger bundles as in *F. autumnalis*, *F. puberula*, *F. complanata*, *F. laxa* and *F. spadicea*, while even a third band is present in *F. castanea* and *F. thermalis*, these two species being the most robust of this genus in North America. The minor structure of the mestome-bundles is the same, all possessing a parenchyma-, a mestome- and an inner, chlorophyll-bearing sheath; besides the relative development of the leptome and hadrome corresponds with what has been said above in the study of the leaf. There are furthermore some leptomatic bundles located in the pith, as mentioned above (fig. 14), but these were only found in one species, *F. castanea.* These small bundles were surrounded by a few layers of thin-walled stereome, also by a sheath, that evidently may be identical with a mestome-sheath; no inner chlorophyll-bearing sheath was observed here, since these bundles occupied an almost central position in the pith.

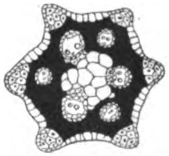

FIG. 13. —Transverse section of the stem of *F. capillaris.* × 75.

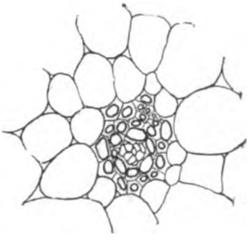

FIG. 14. A leptome-bundle, surrounded by stereome from the pith of *F. castanea;* transverse section. × 320.

The peduncle.

The anatomical structure of the peduncles, which bear the spikes, does not differ in any essential degree from that of the stem. In *F. castanea*, for instance, the peduncle is slightly compressed; the pith occupies a smaller part of the section and has no bundles neither of pure stereome or with leptome.

Tannin was found in both the bark and pith. The same reduction in the size of the pith was, also, observed in *F. laxa* an *F. autumnalis;* in the latter the stereome appeared to hav become more developed than in the stem, forming large groups and, also, by being more thick-walled.

The root.

With the exception of Van Tieghem,* Russow, De Bar and Klinge, very few authors have given account of the roo structure in the *Cyperaceæ.* The elaborate work of Kling to which we have often referred in our articles upon this orde contains a number of detailed descriptions, by which we ar enabled to obtain a broad view of the general structure beside a comparison between the principal characteristics of the root in *Cyperaceæ* and *Gramineæ.* The very important characte to which Klinge has called attention as one of the most reliabl for distinguishing roots of *Cyperaceæ* from *Gramineæ,* th tangential collapsing of the bark-cells, this character has, als been observed by the writer in a number of genera from thi country, including *Fimbristylis.* The structure of the endodermis seems, according to our own observations, to represen a number of variations. This sheath occurs in our species o *Fimbristylis* with more or less thickened cell-walls; in *F. castanea* the thickening appears to have reached the maximum and the individual cells look as if their lumen had almos entirely disappeared. In *F. thermalis* and *F. stenophylla* th endodermis is, also, distinctly thick-walled with a number o layers representing an *O-endodermis.* And in *F. autumnalis* which shows a rather weak mechanical structure, the endodermis is, nevertheless, somewhat thickened, sufficiently to b characterized as an *O-endodermis.* In *F. laxa* the endodermis cells are not thickened all round, but only on the radial an inner walls in the shape of a typical U-endodermis.

In regard to the pericambium, we have only noticed thi tissue as consisting of a single layer of thin-walled cells, or a in *F. castanea* of thick-walled. Otherwise the pericambiun shows the same peculiarity, discussed in the works cited above by Klinge and Van Tieghem: that it does not form a close ring in all the *Gramineæ* and *Cyperaceæ,* but is frequentl interrupted by the protohadrome. It will, however, requir further observation in order to ascertain, whether this fact i common to all or only to certain genera of the *Cyperaceæ* While Klinge has observed the protohadrome to borde immediately on the endodermis, thus breaking through the

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* Van Tieghem, Ph., Recherches sur la symétrie de structure des plantes vasculaires (Annales d. sc. nat., 5th series, vol. xiii, Paris, 1870–71, p 5).

ericambium, in several species of *Carex*, *Eriopharum*, *Scirpus*,
eleocharis and according to Duval-Jouve, also in *Cyperus*
lobosus, *C. fuscus*, *C. vegetus* and *C. serotinus*, Van Tieghem
id not observe this to take place in *Carex brizoides*. More-
ver both Duval-Jouve and Klinge observed a similar separa-
ion of the protohadrome from the endodermis in various
pecies of *Cyperus* and *Galilea mucronata*. In *Carex Fraseri*,
s we have mentioned in a previous article, the protohadrome
, also, separated from the endodermis. The innermost part
f the central-cylinder is in *F. autumnalis*, *F. laxa* and *F.*
hermalis occupied by a single, large vessel, and several in *F.*
astanea and *F. stenophylla*. The conjunctive tissue seems
ost often to be thin-walled, with the exception of *F. castanea*
nd *F. laxa*. The structure of the roots in our species of the
enus does not seem to present any other mechanical protec-
ion than that rendered by the thick-walled endodermis,
lthough we should have expected to find a similar protection
the innermost layers of the bark corresponding to what we
bserved in *Scleria* and *Lipocarpha* with their thick-walled
ark-parenchyma.

These anatomical details, which we have observed in North
merican species of *Fimbristylis*, seem to illustrate that we
ave only one genus before us; the species which by Torrey
ere referred to *Isolepis* appear to be inseparable from the
thers, not only from an anatomical, but, also, from a morpho-
gical viewpoint. And if we consider the various species, as
e have studied them in this country, they exhibit a sufficient
umber of characters which may be regarded as "mutual
ffinities," such as these are understood in orders as large as the
yperaceæ. But it does not seem possible to draw any such
istinction, as for instance to separate the species into "Xero-
hytes or Hydrophytes," even if the local environment might
uggest these plants to belong to different "plant-societies."
ecause the internal structure of the stem, the leaf and the
oot does not furnish any evidence that certain anatomical
eatures are necessarily dependent on a special climate or soil,
either very dry nor very damp. It seems much more natural
imply to acknowledge that such and such species live under
uch and such conditions, even if we, on the other hand, are
nable to account for the similarities and diversities in struc-
ure. The statement that bog-plants may possess xerophytic
haracters and vice versa gives no satisfaction, and is even mis-
eading; characters may have been simply inherited without
eing at present of any particular advantage to the species.
he inner, chlorophyll-bearing sheath may represent a char-
cter of that kind, its function being, so far, unexplainable.

This sheath is, as we have stated above, not especially characteristic of any type of *Fimbristylis*; it is common to our native species and a number from the old world. It is not restricted either to any certain shape of leaf or to species from any peculiar region or locality. Furthermore the relative development of the mechanical tissue in our genus from dry as well as from wet soil furnishes no information regarding a supposed existence of plant-societies with xerophytic or hydrophytic structures; neither the radial arrangement of the palisade-cells or the presence of a parenchyma-sheath. Hence an attempt to classify our native species of *Fimbristylis* as "xerophytes or hydrophytes" would seem very unnatural and not in conformity with their biological peculiarities.

Brookland, D. C., December, 1898.

ART. XLIX.—*On Roscoelite;* by W. F. HILLEBRAND and H. W. TURNER, with a note on its chemical constitution by F. W. CLARKE.

ANALYSIS AND COMPOSITION, BY W. F. HILLEBRAND.

THE rare mineral roscoelite has greatly needed reëxamination in order to reconcile the discrepancies between the analyses of Roscoe and Genth and to establish a satisfactory formula for this supposed vanadium mica. To the kindness of Mr. G. W. Kimble of Placerville, Cal., I am indebted through Mr. H. W. Turner for specimens from the Stockslager mine, from which a limited amount of fairly pure material was picked out. This was then laboriously purified by the aid of Thoulet's solution, the result being a very nearly pure product weighing only 1·2 grams and having after drying at 100° C. a density of 2·97 at 20° C.

Notwithstanding the small amount, it was possible by the exercise of care to make fairly satisfactory analyses.

With regard to the methods employed little need be said except as to the determination of the condition of the vanadium. For this purpose decomposition was effected by rather dilute H_2SO_4 in sealed tubes, the greatest care being taken to expel every trace of air from the powder and acid and to seal the tube during passage of a current of CO_2. Otherwise it is impossible to prevent oxidation of a considerable part of the V_2O_3. In one case, unfortunately, the air cannot have been fully expelled, for the solution after decomposition was blue instead of green and much less oxygen was required in titration than when the color was green.

The contents of the tube, still warm, were poured into fairly hot freshly boiled water and titrated rapidly. Iron and vanadium were then reduced by H_2S gas, the latter boiled out in a current of CO_2, and titration repeated on the hot liquid. The solution was then boiled with ammonia, the precipitate fused with Na_2CO_3, leached with water, and the residue again fused with Na_2CO_3 and leached to remove the last of the vanadium. This residue was then fused with $KHSO_4$,* dissolved in dilute H_2SO_4, boiled first with H_2S and then in a current of CO_2, and the liquid titrated for total iron. The solution held titanium which was then estimated colorimetrically.

The first of the titration results gave the effect of all iron, assuming its existence as FeO, and of all vanadium that might exist in a lower state of oxidation than V_2O_5. The second gave all iron as FeO and all vanadium as V_2O_4. Deduct from both the figure for FeO and the remainder gives that for vanadium. In this way two very concordant results were obtained for total vanadium as V_2O_4 which were supplemented by tests on portions used for other constituents, but only one was obtained for the vanadium as it exists in the mineral, a second being vitiated by evident oxidation during decomposition in the tube. As a check, however, a fresh sample of unpurified mineral was similarly treated and it was found that fully nine-tenths of the vanadium existed as V_2O_3, a result confirming the single test on the purified material which showed 93·5 per cent as V_2O_3. It is not impossible that slight oxidation had taken place even in these cases, and I feel justified in assuming with Genth that the vanadium should be considered wholly as V_2O_3.

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* Any slight trace of vanadium remaining will impart a bright yellow color to the cold $KHSO_4$ fusion, a test which proved useful more than once during the analysis.

In the other portions analyzed the vanadium was likewise titrated in V_2O_4 condition, but only after separation from iron, titanium and aluminum by fusion with Na_2CO_3, extraction with water and separation of dissolved alumina by ammonium carbonate. A second fusion of the residue and of the precipitated alumina was necessary in order to extract all the vanadium. These numerous manipulations render the figures for Al_2O_3 perhaps the least trustworthy of all, but the average given is probably not far from correct.

The iron is assumed to be present as FeO; and the titanium to belong to a foreign mineral, since a test on unpurified material gave much more, namely, 1·50 per cent TiO_2, without accompanying increase in FeO, which latter observation seems to exclude ilmenite as the source of the titanium.

Both the iron and magnesium are supposed to belong to the roscoelite, since they were found by Genth in nearly the same amounts and no recognizable iron or magnesium minerals were noticed in the purified powder.

For comparison, the mean of Roscoe's analyses and that one of Genth's considered by himself to be his best are also given in the table on the following page.

Very marked differences are apparent in the three analyses by different chemists. If titanium was present in the material analyzed by Genth and Roscoe, as is very probable, their high results for alumina are in great part at least accounted for. It is inconceivable how Genth obtained his value for water by ignition, since the mineral oxidizes when heated in air. In fact the oxidation in one of my own analyses, after allowing for loss of water as ascertained by direct weight, was almost what theory requires for the oxidation of V_2O_3 to V_2O_5 and of FeO to Fe_2O_3, or 5·14 per cent instead of 5·27 per cent. It nay fairly be assumed that his water was weighed directly fter expulsion by ignition of the powder. Roscoe's figures or water, if not for moisture, must be affected by error, probbly arising from the unsuspected oxidation of vanadium.

ANALYSES OF ROSCOELITE.

oount sed.	Hillebrand.						Genth.	Roscoe.	
	·3000*g*.	·2531*g*.	·2635*g*.	·1560*g*.*	·2038*g*.	Mean.			
......	45·30	45·04				45·17	47·69	SiO_2	41·25
......	·77		·77		·80	·78		V_2O_5 ...	28·60†
s	23·90	24·00		24·09	24·06	24·01	20·56	Al_2O_3 ..	14·14
),.....		11·74	11·34			11·54	14·10	Fe_2O_3 ..	1·13
......	1·59			1·65	1·57	1·60	1·67	Mn_2O_3 ..	1·15
)	1·64					1·64	2·00	CaO	·61
......		10·41	10·32			10·37	7·59	MgO ...	2'01
).....		·13	none			·06	·17	K_2O	8·56
......		ft. tr.				ft. tr.	tr.	Na_2O ...	·82
below 5° C...	·40					·40		Water .. Moisture	1·08 2·27
) 105–0° C. .	·17		4·29			·17	4·96 ign.		101·62
above 0° C...						4·12			
......						none			
						99·86	98·76		

From the column of means of my own analyses the following ratios are obtainable :

SiO_2	·753
V_2O_3	·159
Al_2O_3	·113
FeO	·022
MgO	·041
K_2O	·110
H_2O	·229

The entire absence of manganese and of calcium in my own nd Genth's samples tends to confirm the suspicion that Rosoe's material was far from pure. It is to be remarked, howver, that my figures for vanadium agree quite closely with his nd differ widely from Genth's.‡

Discrepancies of this kind are not necessarily to be ascribed o faulty analyses. It is well enough known that in any one

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[*] 4·94 per cent oxygen used for complete oxidation instead of 5·27 needed or all V as V_2O_3 and Fe as FeO.

[†] Equivalent to 23·59 per cent V_2O_3.

[‡] This agreement is probably more apparent than real for the reason that oscoe's figure would be materially lowered by regarding the iron of his analysis s FeO instead of Fe_2O_3 in conformity with my analysis.

species of mica various molecules must sometimes be assumed to exist in different proportions and the general formula for such a species can only be arrived at by comparison of a series of analyses of different varieties. Hence, in view of the lack of any simple ratios, the deduction of a definite and final formula from my data is not justifiable. Further analyses are needed of new and very pure material from other locations even if these be not far removed from the source of the present material. Nevertheless, in the hands of an expert very unpromising data may often be made to afford positive indications, and that this is true in the present case the following discussion by Professor F. W. Clarke clearly shows.

CHEMICAL CONSTITUTION OF ROSCOELITE, BY F. W. CLARKE

The ratios given in the foregoing new analysis, used directly lead to the following empirical formula for roscoelite :

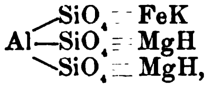
$$H_{458}K_{220}Fe_{22}Mg_{41}Al_{226}V_{316}Si_{753}O_{2724}.$$

Here H to K, and Mg to Fe are as 2 to 1. Between O and Si however, the ratio is not simple, and lies below the orthosilicate and above the trisilicate proportion. Since in many mica the groups SiO_4 and Si_3O_8 are replaceable, that suggestion may be followed out here; and then the formula reduces to

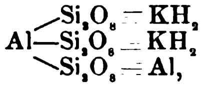
$$R'_{678}R''_{63}Al_{226}V_{316}(SiO_4)_{636}(Si_3O_8)_{71}.$$

From this expression, applying Clarke's mica theory, the mineral may be regarded as a molecular mixture of the thre compounds

1.



2.



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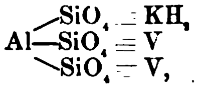

in the ratio 21 : 22 : 159, or nearly 1 : 1 : 8. Upon reducing th analysis to 100 per cent, after throwing out the TiO_2 and th water lost below 280° as extraneous, we get the following comparison between the results found and the theoretical composition.

	Found.	Reduced.	Calculated.
SiO_2	45·17	45·88	45·52
TiO_2	·78	----	----
V_2O_3	24·01	24·39	24·64
Al_2O_3	11·54	11·73	11·62
MgO	1·64	1·66	1·72
FeO	1·60	1·63	1·55
K_2O	10·37	10·53	10·81
H_2O, 280°—	·57	----	----
" 280°+	4·12	4·18	4·14
	99·80	100·00	100·00

his comparison, based on the ratio 21 : 22 : 159, is as satisfacory as could be expected.

Of these component molecules, the first represents the normal hlogopite type: the second is a trisilicate alkaline biotite; nd the third, which forms 74·5 per cent of the whole mass, is muscovite in which two-thirds of the aluminum have been eplaced by vanadium; in short, a vanadium muscovite. Ordiary muscovite is $Al_3(SiO_4)_3KH_2$; and whether a correspondng $V_3(SiO_4)_3KH_2$ exists, can be determined only by analyses f roscoelite from other localities, and so learning its range of ariation. That vanadium may replace aluminum is shown by he fact that Piccini has prepared true vanadium alums. That oscoelite is essentially a vanadium muscovite seems to be fairly vell established. As for the molecule $Al_2(Si_3O_8)_3K_2H_4$, its xistence is indicated in some other micas; and in Simmler's helvetan" it seems to be the dominant molecule.

THE OCCURRENCE OF ROSCOELITE, BY H. W. TURNER.

According to H. G. Hanks,* at one time State mineralogist f California, attention was first called to roscoelite by Dr. ames Blake at a meeting of the San Francisco Microscopical ociety, July 2d, 1874. The specimens then exhibited were rom the Stockslager† mine, which is about 1^{klm} southwesterly rom Lotus on Granite Creek in Eldorado County.

At a meeting of the California Academy of Sciences held uly 20, 1874, Dr. Blake presented specimens of the same ineral, which he then supposed to be a chromium mica.

At a meeting of the California Academy held August 2, 1875,‡ Dr. Blake read a paper on roscoelite. Samples sent by im to Dr. Genth of Philadelphia were found to contain anadium. The mineral was named by Blake in honor of Professor Roscoe of Manchester, England, who had made anadium a special study. Dr. Blake calls attention to the fact that Dr. Hall found vanadium widely diffused in many rocks, generally associated with phosphorus. According to Hanks the Stockslager vein from which the roscoelite obtained by Dr. Blake was taken, is small and not continuous, varying from two inches to a foot in thickness and running nearly parallel with Granite Creek. Associated with the quartz is calcite, and there are at least two varieties of iron sulphide present, probably pyrite and chalcopyrite. Hanks states further that the gold occurs only with the roscoelite and is found interstratified with the roscoelite laminæ in pieces from the value of one dollar to the minutest microscopic particles He also states that from four to five hundred pounds of ros coelite were obtained by the miners, all of which was wasted i extracting the gold.

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* Second Ann. Rep. State Mineralogist of California, pp. 263–4, 1880–2.

† According to Lindgren (see Economic Sheet of the Placerville folio of the Geol. Atlas of the U. S.) this name should be spelled as above, but Hanks spells it *Stuckslager*.

‡ Proceedings Cal. Acad., vol. vi, p. 150, 1875

Mr. George W. Kimble of Placerville, California, for man years county surveyor, has furnished the California materia analyzed by Dr. Hillebrand as well as other specimens. I these specimens the roscoelite is in part embedded in quart and probably contemporaneous in formation with the quart and in part fills little cracks in the quartz and therefore some what later.

There are given below four localities where roscoelite ha been found, according to Mr. Kimble, to whom the author i indebted for the following information about the occurrence o the mineral at these localities.

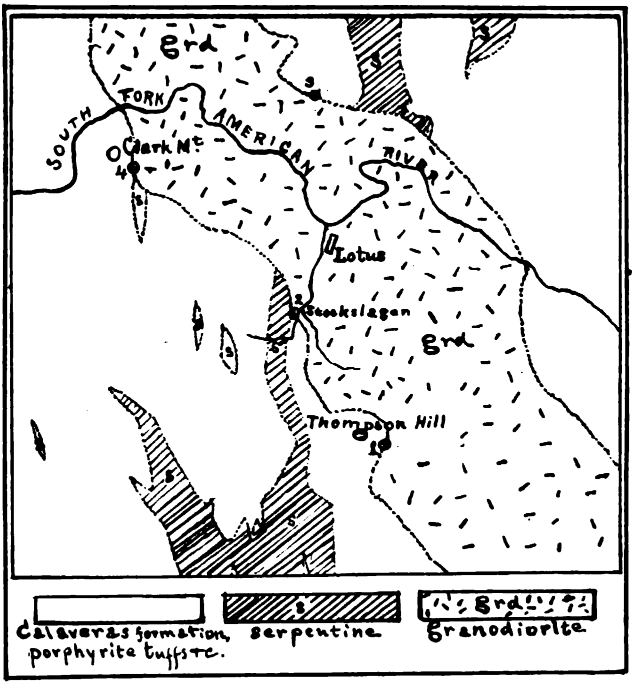

FIG. 1. Geological map copied from the Placerville folio, showing roscoelit localities. Geology by W. Lindgren.

The accompanying map, on the scale of about 1-150000, give the exact localities where the roscoelite has been found. Th Calaveras formation is largely of Carboniferous age, as ma also be the augite-porphyrite tuff associated with it. The serpentine is later than the Calaveras formation and earlier than the granodiorite, which is probably late Jurassic or early Cretaceous. It will be observed that all of the localities are at or near the contact of an intrusive granodiorite mass with the surrounding rocks, chiefly sediments and older lavas. This suggests that the mineral may be regarded as in some way due to the mineralizing solutions accompanying the intrusion of the granodiorite. However, the quartz veins clearly fill fractures which formed in the granodiorite and associated rocks after the consolidation of the granodiorite; consequently the deposition of the quartz and the associated gold and roscoelite must have been also subsequent to the consolidation of the granodiorite. The following are the localities reported by Mr. Kimble. They are all in Eldorado County, from 8 to 15^{klm} northwest of Placerville.

Locality 1. Thompson Hill on its northeast slope about $2{\cdot}5^{\mathrm{klm}}$ southeast of the Stockslager mine.—There are here fifteen or more small seams of quartz having a strike of north of west. As these seams pass through the contact of the granodiorite with the greenstone (augite-porphyrite?) they contain rich spots of gold and roscoelite. The seams of quartz pass on through the northeast point of Thompson Hill and come into the granodiorite again.

Locality 2. Stockslager mine on Granite Creek.—Mr. Lindgren informs me that the vein of the Stockslager mine is in a narrow wedge of metamorphic sediments of the Calaveras formation. Immediately east of this wedge is granodiorite, and immediately west is serpentine. Mr. Kimble states that there is here but one vein of quartz. This passes from the granodiorite into the narrow wedge of the Calaveras formation. It does not penetrate the serpentine. As previously stated, it was at this locality that by far the larger part of the roscoelite was obtained, including that analyzed by Dr. Hillebrand.

Locality 3. South slope of spur about $2{\cdot}7^{\mathrm{klms}}$ north of the village of Lotus.—In micaceous slate, which is part of a contact metamorphic zone of the Calaveras formation. The exact locality is about 500 feet east of the contact. It has never been demonstrated, but Mr. Kimble thinks that this quartz vein extends southeast into the granodiorite.

Locality 4. Clark Mountain on its east slope at the contact of the Calaveras formation and the granodiorite.—The occurrence here is identical with that at the Stockslager mine.

According to Kimble no roscoelite has ever been found where the seams are in granodiorite, and the latter is not altered; but some has been found at the contact of the quartz with serpentine in localities 2 and 4. All of the quartz seams at localities 1, 2, and 4 dip southwest and have pockets of gold.

Prof. Hanks* states that roscoelite was also found in Sec. 31, T. 11 N. Range 10 E. two miles from the Stockslager mine. This appears to be the Thompson Hill locality of Kimble, to whom, indeed, Prof. Hanks was probably indebted for his information. Hanks states that the roscoelite was found here in the bed rock of Big Red ravine in a dark-colored micaceous rock in small seams of quartz with calcite and gold.

The roscoelite from California shows a tendency to crystallize in little rosettes, so that individual scales of any size with the same optical orientation throughout are difficult to obtain. Some scales gave with convergent light a nearly uniaxial black cross, the hyperbolas opening but slightly on rotation, indicating a small axial angle. Like all other micas it is optically negative. The pleochroism as seen in thin foils is, $\mathfrak{c}$ and $\mathfrak{b}$ clove brown to greenish yellow brown, $\mathfrak{a}$ light greenish yellow. In the scales of the powder analyzed no rutile needles or other inclusions were detected, but in the center of a rosette of roscoelite scales were found dark grains with a metallic luster. These grains are of sufficient size to have fallen with the heavy minerals during the process of separation with the Thoulet solution, and it is not likely that any of them have been included in the powder analyzed, although they were noted in the impure material before it had undergone the final separation. The grains show no crystal form and were not determined.

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* Loco citato, p. 263.

ART. L.—*On Gravitation in Gaseous Nebulæ*; by FRANCIS E. NIPHER.

THIS subject has received attention of late through the work of Dr. See, who has rediscovered the law announced by Ritter in 1878. According to Ritter, if R be the radius of a spherical mass of gas of cosmical dimensions, and T its temperature, the product TR = constant. As Ritter announced, the heat capacity of such a gravitating mass is negative. If heat leaves the gas, it contracts and becomes warmer. Dr. C. M. Woodward has recently published a paper* in which he deals with the conditions of equilibrium in such a mass, and he deduced the equation for the mass of the central core of a gravitating spherical nebula

$$M = \frac{2CT_0 r}{K}$$

Here C is the constant for the gas, and M is the mass internal to any radius r. K is the gravitation constant and T_0 is the constant temperature of the mass. Woodward admits that if such a mass could be contracted, its temperature would rise, but he denies that gravitation is competent to contract the gas, and even concludes that such a nebula cannot lose heat by radiation.

The present writer, in the succeeding number of the Transactions, has shown that such contraction is possible; and that when T is made variable in the above formula, the value of Ritter's constant is determined by that equation, in terms of the gravitation constant, the constant for the gas, and the mass M internal to r.

This equation is then applied to a cosmical mass of hydrogen. What must be the physical condition in order that a central mass or core, having a radius equal to that of the sun, should contain a mass equal to that of the sun. The conditions of the problem determine r, C and M; and K being known, the value of T turns out to be 20,000,000 degrees centigrade. The pressure at the surface of this sphere is computed, and it is found to be $3{\cdot}706 \times 10^{14}$ dynes per square centimeter, or 366,000,000 atmospheres. The average density of the spherical mass, which is three times the density at the surface of the hydrogen sun, is about 7 per cent less than the average density of the sun itself. The pressure at a distance of 92 million miles from the center of mass is found to be about 0·4 of an atmosphere.

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* Trans. Acad. of Sci. of St. Louis, vol. ix, No. 3.

The equations show that the same pressures and densities would hold for any other perfect gas. In fact, the above equation shows that if r and M are fixed, the product TC must be constant for all gases. This carries with it the conclusion shown by the other equations, that the average density of such a solar mass is independent of the nature of the gas. This is a matter of great significance, when taken in connection with the fact that the real density of the sun is only slightly greater than the density of the hypothetical hydrogen sun.

The real condition around our sun is, that increasing opacity to radiation as one goes to levels of smaller radius, has retained the heat within the dense nucleus. The rarefied external parts of the solar nebula have parted with their heat and the temperature throughout the mass has ceased to be uniform. Interplanetary pressures have been abolished. Hydrogen would solidify at a distance of 92 million miles from our sun if away from any large mass of matter. And this obliteration of cosmical pressure has almost wholly compensated the fall in temperature of the sun from 20 millions at least to perhaps 10,000 degrees.

The fact that a gaseous mass can apparently contract itself, and heat up in some such way as it would do if it were compressed by the action of some external system, is obviously of profound significance. The clue that it seems to give concerning the nature of gravitation is well worthy of the most serious attention. Is not gravitation the action upon matter of a system wholly external to matter?

ART. LI.—*The Titration of Oxalic Acid by Potassium Permanganate in presence of Hydrochloric Acid;* by F. A. GOOCH and C. A. PETERS.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXII.]

LÖWENTHAL and LENSSEN* were the first to show that the titration of a ferrous salt by potassium permanganate in the presence of hydrochloric acid, according to the process of Margueritte† is vitiated by the evolution of chlorine outside the main reaction, and to point out that a remedy for the difficulty is to be found in the titration of the ferrous salt in divided portions, other equal volumes of the ferrous solution being added to the liquid in which the first titration is accomplished until the amount of iron indicated by successive titrations becomes constant.

Kessler‡ showed the restraining influence of certain sulphates, of manganous sulphate in particular, upon the irregular and undesirable interaction of the permanganate and hydrochloric acid, and Zimmermann,§ in apparent ignorance of Kessler's forgotten proposal, advocated the introduction of a manganous salt, best the sulphate, into the ferrous salt to be determined, thus accomplishing the purpose of the empirical procedure of Löwenthal and Lenssen.

The tendency toward evolution of chlorine in the oxidation of a ferrous salt by permanganate, as compared with the absence of such tendency in the similar oxidation of oxalic acid, in presence of hydrochloric acid, was explained by Zimmermann on the hypothesis that an oxide of iron higher than ferric oxide is formed as an intermediate product, and that this unstable oxide is sufficiently active to break up hydrochloric acid as well as to oxidize more of the ferrous salt. Quite recently, Wagner‖ finds explanation of the sensitiveness of the hydrochloric acid solution of the ferrous salt in the probable formation of chlor-ferrous acid (analogous to chlorplatinic and chlor-auric acids), which suffers oxidation more readily than hydrochloric acid under the action of the permanganate. The protective influence of the manganous salt turns apparently, as Zimmermann suggested, upon the initiation of Guyard's reaction, according to which the permanganate and manganous salt interact to form a higher oxide of manganese of a constitution approaching the dioxide more or less closely—this oxide being capable of oxidizing the ferrous salt, but slow to act upon the hydrochloric acid, or the chlor-ferrous acid of Wagner. According to Volhard* the reaction of Guyard is favored and hastened by heat and concentration of the solution, while it is delayed by acidity and dilution; but even in solutions containing very little manganous salt and a considerable quantity of free acid the faint rose color developed by the careful addition of permanganate ultimately vanishes until every trace of the manganous salt is precipitated. When a considerable amount of the salt is present interaction follows immediately the introduction of the permanganate. Zimmermann advocates the use of 4 grams of manganous sulphate uniformly in titrations of a ferrous salt by permanganate, a procedure to which Wagner gives acquiescence, though pointing out that a ninth of that amount is all that he finds to be necessary. The excess of the manganous salt can do no harm so long as the higher oxide, the product of interaction of the manganous salt and the permanganate, is immediately reduced by even traces of a ferrous salt, and this appears to be the case at least within the limits proposed by Zimmermann and Wagner. Thus we find, as shown in results of the accompanying table, that so much as five grams of the sulphate may be present in 135^{cm^3} of the liquid, containing about 5^{cm^3} of hydrochloric acid of full strength, without interfering with the regularity of the titration; and the effect is trivial even when the amount of manganous sulphate reaches ten grams. We find also practical regularity of working when manganous chloride is substituted for the sulphate, and in this respect our results accord with those of Zimmermann and differ from those of Wagner.†

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* Zeit. f. Anal. Chem., i, 329. † Ann. d. Chim. et d. Phys. [3], xviii, 244.

‡ Ann. d. Phys. u. Chem., cxviii, 48; cxix, 225–226.

§ Ann. d. Chem., ccxiii, 302.

‖ Maasanalytische Studien, Habilitationsschrift, Leipzic, 1898.

Total volume at beginning of titration. cm^3.	HCl Sp. gr. 1·09. cm^3.	$FeCl_2$. cm^3.	$KMnO_4$ $\frac{1}{10}$ N. cm^3.	$MnSO_4 . 5H_2O$. grams.	$MnCl_2 . 4H_2O$. grams.
135	10	25	21·70	1·	....
135	10	25	21·70	3·	....
135	10	25	21·70	5·	....
135	10	25	21·75	7·	....
135	10	25	21·75	10·	....
145	20	25	21·75	10·	....
175	50	25	21·75	10·	....
135	10	25	21·70	....	1·
135	10	25	21·70	....	2·
145	20	25	21·70	....	2·
155	30	25	21·75	. ..	3·
165	40	25	21·70	....	4·

In all cases, however, in which the larger amounts of manganous salt are present, the end reaction is marked by the advent of a brownish-red precipitate rather than the clear pink of the soluble permanganate, and it is obvious that in case the solutions to be oxidized were not active enough to act with rapidity upon the product of the Guyard reaction, difficulty might follow the failure to adjust the conditions more particularly.

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* Ann. d. Chem, cxcviii, 318, 1879.

† Loc. cit., p. 104.

It has been stated by Fleischer* and Zimmermann† that hydrochloric acid interferes in no way with the titration of oxalic acid by potassium permanganate. This statement, however, is not in accord with our experience; for we find that in such titrations there is a small though real waste of permanganate proportionate to the amount of hydrochloric acid present. This fact is brought out clearly in the comparison of experiments of section A in the following table, in which no hydrochloric acid was present, with experiments B, in which hydrochloric acid was present.

Temperature at beginning about 80° C.

Approximate volume at beginning of titration.	H_2SO_4 1:1 cm³.	HCl Sp. gr. 1·09. cm³.	Ammonium oxalate $\frac{1}{10}$ N. cm³.	$KMnO_4$. cm³	Variation from mean of A taken as standard. cm³.
			A		
200	5	....	50	47·50	0·00
200	5	....	50	47·50	0·00
200	10	....	50	47·50	0·00
200	10	....	50	47·50	0·00
200	25	....	50	47·50	0·00
200	25	....	50	47·50	0·00
			B		
150	10	2·5	25	23·80	+0·05
150	10	2·5	25	23·90	+0·15
150	10	5·0	25	23·90	+0·15
150	10	10·0	25	24·00	+0·25
500	5	.....	25	23·80	+0·05
500	10	10·0	25	24·00	+0·25
500	10	10·0	25	24·10	+0·35

From these results it is evident that, though the error introduced by the presence of the hydrochloric acid during the action of the permanganate upon the oxalic acid is small, it is plainly appreciable. The questions arise, therefore, first, as to whether the secondary action of the permanganate upon the hydrochloric acid may be prevented by the presence of a suitable amount of a manganous salt, and, secondly, as to whether in this event the reducing agent,—the oxalic acid—is sufficiently active, like the ferrous salt, to prevent the premature establishment of an end color due to the Guyard reaction. The latter question must naturally be settled before the former can be taken up. In the accompanying table are recorded the effects of varying amounts of manganous salt in presence of different amounts of sulphuric acid in the reaction of permanganate upon oxalic acid.

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* Volumetric Analysis; Trans. by Muir, p. 71. † Loc. cit.

Temperature at beginning about 80° C.

Volume at beginning. cm³.	H_2SO_4 1 : 1. cm³.	Ammonium oxalate. $\frac{1}{10}n$ cm³.	$MnSO_4.5H_2O$. grams.	$KMnO_4$. cm³.	Variation from standard.
130	5	25	----	23·75	0·00
130	5	25	0·0008	23·75	0·00
130	5	25	0·0032	23·75	0·00
130	5	25	0·0160	23·75	0·00
130	5	25	1·	23·70	−0·05
130	5	25	2·	23·75	0·00
130	5	25	2·5	23·60	−0·15
130	5	25	3·0	23·40	−0·25
130	5	25	4·0	23·60	−0·15
500	5	25	----	23·80	+0·05
500	5	25	0·0008	23·80	+0·05
500	5	25	0·0032	23·80	+0·05
500	5	25	1·	23·70	−0·05
500	5	25	2·	23·40	−0·35
500	5	25	3·	23·50	−0·25
500	5	25	4·	23·30	−0·45
130	10	25	1·	23·80	+0·05
130	10	25	2·	23·75	0·00
130	10	25	3·	23·65	−0·10
130	10	25	4·	23·50	−0·25
130	15	25	2·	23·75	0·00
130	15	25	4·	23·70	−0·05
130	15	25	5·	23·50	−0·25
130	30	25	2·	23·75	0·00
130	30	25	4·	23·70	−0·05
130	30	25	5·	23·75	0·00

From the results given it is evident that the persistence of the Guyard reaction is liable to interfere with the end reaction of oxidation of oxalic acid unless an adjustment is made between the quantity of the manganous salt, the amount of acid, and the dilution. In hot solutions of a total volume of 130^{cm^3} at the beginning, no more than 2 grams of the manganous sulphate should accompany 5 to 10^{cm^3} of the 1 : 1 sulphuric acid; when the total volume at the beginning reaches 500^{cm^3}, no more than a single gram of the salt should be present with 5^{cm^3} of the 1 : 1 sulphuric acid. The amount of manganous salt may, however, be increased considerably if the quantity of acid is increased.

As Kessler has noted, a sufficiency of the manganous salt, acting no doubt as the medium of transfer of oxygen, may bring about interaction between the permanganate and the oxalic acid at atmospheric temperatures without the tedious delay ordinarily encountered in the attempt to consummate that action in cold solutions. It would seem natural that the manganic hydroxide formed in the Guyard reaction at low temperatures should yield more readily to the reducing action of the oxalic acid than the more anhydrous form to be expected in hot solutions, so that at such temperatures the limits as to proportions of manganous salt, acid, and dilution, within which favorable action may take place, should be wider; moreover, the undesirable action of the permanganate upon hydrochloric acid, when that acid is present, should be less appreciable at lower temperatures. In our experiments, therefore, upon the oxidation of oxalic acid by potassium permanganate in presence of hydrochloric acid, we have studied the effect of varying the proportions of the manganous salt both at atmospheric temperatures and the higher temperatures generally employed.

Temperature 20°-26° C.

Number of experiment.	Volume at beginning of titration.	H_2SO_4 1 : 1 cm³.	HCl Sp. gr. 1·09. cm³.	Ammonium oxalate $\frac{1}{10}$ N. cm³.	$KMnO_4$. cm³.	$MnSO_4 . 5H_2O$. grams.	$MnCl_2 . 4H_2O$. grams.	Variation from standard. cm³.
1	130	....	10	25	23·90	·0040	....	+0·15
2	130	....	10	25	23·90	·0120	....	+0·15
3	130	....	10	25	23·80	·0250	....	+0·05
4	130	....	10	25	23·75	·0400	....	+0·00
5	130	....	10	25	23·76	·0500	....	+0·01
6	130	....	10	25	23·70	·1000	....	−0·05
7	130	....	10	25	23·75	·2000	....	0·00
8	130	....	10	25	24·20	....	·0200	+0·45
9	130	....	10	25	23·95	....	·0200	+0·20
10	130	....	10	25	23·80	....	·0400	+0·05
11	130	....	20	25	23·75	....	·0400	0·00
12	130	....	30	25	23·75	...	·0400	0·00
13	130	....	10	25	23·75	1·0000	....	0·00
14	130	....	10	25	23·75	2·0000	....	0·00
15	130	....	10	25	23·75	3·0000	....	0·00
16	130	1	....	25	23·72	....	1·0000	−0·03
17	130	1	....	25	23·74	....	2·0000	−0·01
18	130	1	....	25	23·72	....	3·0000	−0·03
19	130	2	....	25	23·70	....	0·5000	−0·05
20	130	3	....	25	23·75	....	0·5000	0·00
				Temperature about 80°.				
21	145	10	10	25	23·90	0·5000	....	+0·15
22	145	10	10	25	23·70	1·0000	....	−0·05
23	500	10	10	25	23·75	1·0000	....	0·00
24	500	....	10	25	23·70	1·0000	....	−0·05
25	500	....	10	25	24·10	0·5000	....	+0·35

From these results it appears that the presence of a suitable amount of manganous salt—either the sulphate (exps. 4–7, 13–15, 22–24) or the chloride (exps. 10–12, 16–20)—is capable, either in cold solution (exps. 1–20) or in hot solution (exps. 22–24) of preventing the action of the permanganate upon the hydrochloric acid. It appears, also, that, for a given dilution and strength of acid, less manganous salt is needed in the cold solution (exps. 4–7) than in the hot solutions (exps. 22–24). Thus, in the hot solution, at a dilution of 145^{cm^3} to 500^{cm^3} 1 grm. of manganous sulphate must be present with 5^{cm^3} of strong hydrochloric acid, with or without sulphuric acid; while in the cold solution 0·04 grm. of either the sulphate or chloride is enough to secure adequate protective effect. Experience showed, however, that 0·5 grm. or 1·0 grm. of the manganous salt should be present in order to push the reaction with reasonable speed in cold solutions.

Wagner* has made record of the increased evolution of chlorine in oxidations of ferrous chloride by potassium permanganate in presence of various salts, of which barium chloride was the most active. We have made some experiments, therefore, to determine whether such action would appear in the oxidation of oxalic acid in cold solutions containing certain salts, and, if so, whether it would be preventable by the presence of the manganous salt under our conditions of working. From the results given in the accompanying table, it is plain that the evolution of chlorine in cold solutions is less in the presence of these salts than when hydrochloric acid is used without them, and that such evolution may be entirely prevented (within the proportions of our work) by the presence of 0·5 grm. to 1 grm. of manganous chloride.

Finally, it appears as the result of an investigation, that the titration of oxalic acid by potassium permanganate in presence of hydrochloric acid is ordinarily attended with some inaccuracy due to liberation of chlorine from the hydrochloric acid; that this tendency may be overcome by the presence of a manganous salt—either the sulphate or chloride; that 1 grm. of the manganous salt is enough to so affect the conditions of equilibrium that titrations in moderate volumes (100^{cm^3} to 500^{cm^3}) and in presence of hydrochloric acid (5^{cm^3} to 15^{cm^3} of the strong acid) may be conducted with safety and reasonable rapidity, either with or without sulphuric acid, at the ordinary atmospheric temperature.

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* Loc. cit.

VOLUME AT BEGINNING OF TITRATION = 140$^{cm^3}$.
Temperature = 20°–24° C.

Ammonium oxalate. cm³.	HCl. strongest cm³.	$MnCl_2.4H_2O$.	$BaCl_2$. grams	$SrCl_2$. grams.	$CaCl_2$. grams.	$MgCl_2$. grams.	$KMnO_4$ used. cm³.	Error. cm³.
25	5	0·5	--	--	--	--	26·05	0·00
25	5	--	--	--	--	--	27·45	+1·40
25	5	--	2	--	--	--	26·50	+0·45
25	5	--	--	2	--	--	26·53	+0·48
25	5	--	--	--	2	--	26·36	+0·35
25	5	--	--	--	--	2	26·13	+0·08
25	5	0·5	2	--	--	--	26·05	0·00
25	5	0·5	--	2	--	--	26·10	+0·05
25	5	0·5	--	--	2	--	26·10	+0·05
25	5	0·5	--	--	--	2	26·05	0·00
25	10	1·0	2	--	--	--	26·10	+0·05
25	10	1·0	--	2	--	--	26·05	0·00
25	10	1·0	--	--	2	--	26·06	+0·01
25	10	1·0	--	--	--	2	26·11	+0·06

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Influence of Electric Oscillations on Vapors.*—It ha been pointed out by **Kauffman** that when the vapors of variou chemical compounds are subjected to the influence of electri oscillatory discharges the results obtained are: (1) the vapo becomes luminous, (2) it is crossed by spark discharges, generall of a green color, or (3) it remains dark, at least until a very hig pressure is reached. More than fifty vapors were examined i this way, and the results, while too few to permit of genera deductions, yet appear to indicate certain constitutive influence Thus, for example, the aromatic amines for the most part becom luminous and show quite similar appearances, the facility wit which luminosity occurs appearing to be partly dependent o the basic character of the amine; since compounds which hav lost their basic character by substitution, such as nitraniline an tribromaniline, no longer become luminous by the discharge Cyclic compounds, however, containing nitrogen, do not appear t follow this rule. In the case of hydrocarbons, aliphatic compounds and the more simple benzene compounds remain dark unti a very high pressure is reached, though most of the hydrocarbons containing two or more benzene rings readily become luminous. During luminosity, it was noticed that in all cases th vapor acted as a conductor.—*Zeitschr. phys. Chem.*, xxvi, 719-727, August, 1898. G. F. B.

2. *On the Occlusion of Oxygen and Hydrogen by Platinum black.*—In experiments made by **Mond**, **Ramsay** and **Shields** t test the occlusion of oxygen and hydrogen in this way, the platinum black was saturated with hydrogen, heated at 184° unde reduced pressure, then placed in an ice calorimeter and allowe to reabsorb the gas. It was found that 68·8 calories were evolve for every gram of hydrogen occluded. In the opinion of th authors the argument offered by Berthelot in support of th existence of the compounds $Pt_{30}H_2$ and $Pt_{30}H_3$ are not justified b the facts. Moreover they conclude that the difference betwee palladium and platinum, in their behavior towards hydrogen, a stated by Favre, is due simply to the presence of oxygen in th platinum black. On attempting to remove the oxygen fro platinum black, in order to determine its heat of occlusion, it wa noticed that reducing agents, while eliminating the oxygen, wer themselves occluded and retained obstinately. It was als observed that hydrogen does not remove all the oxygen, but onl replaces that at first removed, both gases being simultaneousl occluded. On saturating platinum black with hydrogen an exhausting it at 184°, it was found that, on allowing it to come i contact with small quantities of oxygen, the addition of mor oxygen beyond a certain point, caused the pressure to increase

On adding oxygen, however, up to atmospheric pressure, a further small quantity of the gas was absorbed and the heat simultaneously developed represented the true heat of occlusion of this quantity of oxygen. The results obtained were in close agreement with others obtained indirectly, giving as a mean 11 calories for every gram of oxygen occluded. This value agrees well with that given by Thomsen for the heat of formation of platinous hydroxide. Possibly, therefore, the two phenomena may be identical, the water required being present in platinum black dried in a vacuum.

In a subsequent investigation, the authors studied the action of palladium black in occluding gases. Prepared in the same way as platinum black, it contains 1·65 per cent or 138 times its volume of oxygen. But this oxygen, unlike that in platinum black, cannot be removed by heating to dull redness in a vacuum, but must be heated in a current of hydrogen. When heated in oxygen the palladium black absorbs it, up to a red heat, yielding a brownish black substance, which does not lose its oxygen on heating to redness in a vacuum. Nearly 1000 volumes are absorbed, an amount about three-fourths of that required to form the oxide PdO. Over 1000 volumes of hydrogen are absorbed by palladium black, though only 873 volumes are occluded, the rest having formed water with the oxygen present. About 92 per cent is removed by the air pump at the ordinary temperature, the rest at 444°. The palladium sponge from this experiment occluded 852 volumes of hydrogen, of which 98 per cent was extracted in a vacuum at ordinary temperatures. The heat of occlusion for hydrogen was found to be 46·4 calories for each gram of the gas; or 43·7 if the work of the atmosphere be allowed for. The heat developed per gram of oxygen occluded, determined indirectly, was found to be 11·2 calories, a value intermediate between that found by Thomsen for the heat of formation of palladious and palladic hydroxides; favoring the idea that this occlusion of oxygen is a true oxidation. The atomic ratio of palladium to hydrogen in the fully charged metal varies between 1·37 and 1·47; agreeing closely with the formula Pd_3H_2 as suggested by Dewar. —*Proc. Roy. Soc.*, lxii, 50–52, 290–293; *J. Chem. Soc.*, lxxiv, ii, 599, 600, December, 1898. G. F. B.

3. *On certain Derivatives of Acetylene.*—It has been observed by ERDMAN and KÖTHNER that when acetylene is passed over finely divided copper heated to 400°–500° it is decomposed into hydrogen and carbon, the latter appearing in the graphitic condition. At temperatures below 250°, however, the copper unites with the gas, forming a yellowish-brown compound which is not explosive. This new substance may be more readily prepared by heating finely divided cuprous oxide in a current of acetylene at 250°. It is very bulky, and has the composition $C_{44}H_{64}Cu_2$. When heated with zinc dust in excess it yields 20 per cent of an oil having an odor like Caucasian naphtha and boiling between 190° and 250°. Well-defined acetylides of the alkali metals are

not easy to prepare. Rubidium, though acted on by acetylene at low temperatures, gives rise to no definite product. Zinc and mercury are scarcely acted on, and iron, like copper, acts catalytically, inducing condensation to oily hydrocarbons. Acetylene produces no precipitate in solutions of thallium, lead, cadmium, iron, nickel, cobalt, platinum, iridium, and rhodium. Gold chloride gives a black precipitate, changing to metallic gold on warming. Palladium chloride gives a brown precipitate soluble in ammonia. Copper acetate yields a brownish-red and silver nitrate a white precipitate. By saturating a hot solution of mercuric nitrate with acetylene, mercurocarbide nitrate $HgC \vdots CHg.HgNO_3.H_2O$ separates in small white crystals. It yields acetaldehyde on treatment with dilute acids.—*Zeitschr. anorg. Chem.*, xviii, 48–58, 1898.

G. F. B.

4. *On Eutropic Series of the Calcium Group.*—In 1896 Linck proposed the term catameric eutropy or more briefly eutropy, for those special cases of isomorphism in which the geometrical and physical characters of members of a series increase or decrease regularly with increase of the atomic mass of the varying element; as is the case for example in the potassium, rubidium and cæsium compounds described by Tutton. Subsequently he called attention to the fact that the quotients obtained by dividing the crystal volumes of the different members of such a series by their molecular volumes are in the ratio of simple natural numbers.

These relations have been recently tested by **Eppler**, who finds that they both hold good in the calcium-barium-strontium group, with one or two exceptions, as in the case of the three anhydrous sulphates, anhydrite, celestite and barite. In his paper he has brought together and compared numerous data concerning the crystallized compounds of this series of elements, giving new geometrical, optical and density determinations. In the case of cubic crystals the volume is unity and the above mentioned quotient is inversely proportional to the molecular volume. In the cubic oxides, fluorides, chlorides and nitrates of calcium, strontium and barium, the ratios are 11 : 15 : 19, 14 : 17 : 20, 18 : 19 : 20, and 20 : 21 : 22 respectively; thus decreasing with the increase in molecular mass. Although lead compounds are frequently isomorphous with those of calcium, strontium and barium, they do not belong to the same eutropic series, the physical constants falling between those of calcium and strontium or before or after those of the barium salt corresponding.—*Zeitschr. Kryst. Min.*, xxx, 118–175; *J. Chem. Soc.*, lxxiv, 560, December, 1898.

G. F. B.

5. *The distribution of Vanadium.*—It was shown by **Hasselberg** in 1897 (Astrophys. Jour., vi), that the mineral rutile contains vanadium in small but varying amount. He has now (ibid., ix, 143) continued his investigation to a considerable number of meteoric stones, and concludes from this that vanadium is always present in them, although it has not been detected in meteoric irons. A recent paper by Hillebrand (this Journal, vi, 209) has

shown that both vanadium and molybdenum are widely distributed in rocks, the former probably present in the silicates of the amphibole or pyroxene group and in the biotites.

6. *Determination of time of vibration of very high notes.*—F. **Melde** reviews the various methods that have been suggested and used for such determinations and divides them into two groups: A, the subjective; B, the objective. Under A fall the determinations carried out by the human ear, such as the comparison of sounds, one of which is used as a standard. Determinations of notes of 6144 vibrations have been made by this method; for higher notes the method becomes inapplicable. To the subjective method also belongs the difference-tone method, which consists in measuring a third tone by the use of two primary tones. Notes of 8692 vibrations have thus been measured. To the objective method belong the various graphical and photographic methods. In conclusion the author points out the applicability of sensitive flames for the measurement of high notes.—*Wied. Ann.*, No. 4, 1899, pp. 781–793. J. T.

7. *Heat conductivity of different kinds of glass.*—A great number of determinations have been made by Focke and by Paalhorn of the thermal conductivity of glass which differ greatly in value. A. **Winkelmann** endeavors to reconcile the results and concludes that it cannot be decided which determinations are the better. The discrepancies are in part due to the different ranges of temperature employed. The author concludes that it is desirable to investigate further the dependence of the conductivity of glass upon temperature.— *Wied. Ann.*, No. 4, 1899, pp. 794–802. J. T.

8. *Absorption of Electric Waves by different substances.*—The recent experiments in wireless telegraphy have excited interest in the question of the electrical opacity of non-metallic substances. E. **Branly** and G. **Lebon** have undertaken a research upon this question. A coherer together with a battery and a bell were placed in a cavity in the substance which was to be investigated. The substances employed were stones, blocks of cement, and boxes of sand. The electric waves were excited by a Rhigi oscillator placed outside the substance. It was found that the opacity depends upon the nature of the substance. The transparency is very great in the case of sand and the kind of building stone employed. It was extremely feeble with Portland cement. The opacity increases with the thickness. Humidity clearly increases the opacity.—*Comptes Rendus*, April 14, 1899, pp. 879–882. J. T.

9. *Radiations of Uranium.*—H. **Becquerel** concludes further study of these radiations by the following conclusions: The radiation of radio-active bodies approaches approximately in character to X-rays more nearly than to ordinary light. The most singular fact connected with these radiations is the spontaneous emission of such radiations without known cause. If it could be shown that this radiation occurs without the consump-

tion of energy, one could compare the state of uranium to tha of a magnet. We can also compare the state of uranium to tha of phosphorescent bodies which seem to conserve their state of phosphorescence indefinitely. The photographic and phosphorescen effect, however, of the uranium radiation indicates a consumptio of energy. This consumption is extremely feeble, and seems t indicate that uranium can emit its unknown radiation for a lon period of years apparently without sensible diminution.—*Compte Rendus*, March 27, 1899, pp. 771–776. J. T.

10. *Source of Uranium Radiations.*—Prof. W. Crookes suggests that uranium, thorium, polonium and radium have the powe of separating rapidly moving molecules from slowly moving one and appropriating a portion of the energy of the former. Thi energy may be used in dissociation and maintaining radiations i the ether. The air in the neighborhood of such substances woul be cooled. This cooling is so small as to escape detection, an therefore the energy appears to be created out of nothing. Th author computes that air contained in a room 4×8×7m. coul supply one h.p. for fifteen hours.—*Comptes Rendus*, 128, pp 176–178, 1899. J. T.

11. *Phosphorescence at low Temperatures.*—A. and L. Lumièr have found that the phosphorescence of calcium and zinc sulphide produced by exposure to an arc light disappears wholly at abou —50° C. When exposed to a magnesium light it disappeare between —70° and —90°. When the exposure to a magnesiu light is made at —191° C. the temperature of liquid air and th body is heated, phosphorescence begins to appear at —180° C. an increases with the heating. Röntgen rays act like ordinary light.—*Comptes Rendus*, 129, pp. 549–552, 1899. J. T.

12. *Recueil Données numériques publié par la Société Françai de Physique. Optique par* H. Dufet. Deuxième fascicule. Propriétés optiques des solides; pp. 417–785, Paris, 1899 (Gauthie Villars).—This volume contains tables of physical constants i the department of optics, prepared under the direction of th Physical Society of France. The opening tables give the refractive indices for different wave-lengths of certain remarkable substances, as calcite, quartz, fluorite, halite, and so on. The follows a table of refractive indices for certain important sample of glass. After this we have an alphabetical list of inorgani solids, largely mineral species, with their optical propertie arranged in tabular form; references are given to the origina publication where the facts were given. This portion cover pages 466 to 632. A like table for organic solids follows, an then other tables giving the influence of temperature on optica properties, and allied subjects, close the volume. This enumeration of its contents will show how much this valuable book o reference contains.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Icthyologia Ohiensis by C. S. Rafinesque, a verbatim reprint;* by R. E. CALL. 8vo, 175 pp. Cleveland, 1899. (The Burrows Brothers Co.)—Rafinesque's genera and species, whether based on actually existing forms or Audubon's cruel jokes, or in later life evolved from his own diseased mind, have been a stumbling block to the systematic zoologist for more than half a century. The extreme rarity of many of his published works has increased the difficulty of recognizing the forms he described and has doubtless often forced subsequent authors to ignore him unwillingly. The late G. W. Tryon many years ago republished Rafinesque's conchological works, and now Dr. Call and his publishers give us the work on American fishes in this handsome volume, issued in a limited edition of 250 numbered copies. The volume contains a brief biographical sketch of Rafinesque, an account of his ichthyological work, a verbatim reprint of the Ichthyologica Ohiensis (of which only eight copies are now known to exist), a bibliography of his papers on fishes, and a reproduction of a previously unpublished letter from Rafinesque to Dr. Daniel Drake of Cincinnati, containing a sketch of one of the fishes described. It seems ungrateful to criticise a work of this kind for its omissions, but a general index is much needed, the reprint of the original index of the Icthyologica with references to the genera and English names being almost useless for reference.

If the "excentric naturalist" could have foreseen the appearance, before the end of the century, of this luxurious volume devoted to a reprint of the work to which he gave himself with such prodigality of unrewarded zeal, he might have forgiven and forgotten the neglect and scorn of his cotemporaries and retained his reason through the unhappy later years of his life. S. I. S.

2. *Elementary Physiology;* by BENJAMIN MOORE, M.A. pp. 295. New York, 1899. (Longmans, Green & Co.)—This elementary text-book differs in several respects from many other books of its class. First, a relatively large portion of the text is devoted to the description of the structure of the animal body. Since the functions of the organism are so closely connected with its morphological characters, a somewhat comprehensive survey of the latter becomes highly essential to a well-conducted course in physiology for beginners. The usefulness of the present text-book is greatly increased by an unusually large number of well-selected illustrations. Second, in the consideration of the various departments of physiology due appreciation of the relative importance of the phenomena discussed has usually been shown. Too many of the elementary text-books are unsatisfactory in this respect: they either unduly emphasize certain actions of the body, or omit entirely chapters which do not permit of easy treatment. Professor Moore's little book certainly does not err in the latter respect, and it may even be questioned whether occasional topics

have not been introduced with too great detail for the beginner. Third, the reader is not allowed to forget that physiology is an experimental science and should properly be taught as such; accordingly, the general method of the book tends to encourage observation and experiment. A series of carefully defined exercises forms a useful appendix. L. B. M.

3. *Experimental Morphology, Part II;* by C. B. DAVENPORT. New York, 1899.—In this second installment of his valuable treatise Dr. Davenport considers the effects of chemical and physical agents on growth. Plants lend themselves so readily to observations respecting growth, that they have received from Dr. Davenport a degree of attention in this work which compels the student of plant physiology to accept his aid. The literature of the whole province has been carefully examined, and few omissions can be noted in the references. On the whole, the editorial work has been wonderfully well done, and the errors are so few that they need not be mentioned here; they do not appear likely to mislead seriously any students who make use of the vast amount of material which has been gathered patiently, and for the most part has been well arranged. The botanical phases of experimental morphology are at present attracting a large number of enthusiastic students who are moved to consider questions in a broad way, and are stimulated by just such books as Dr. Davenport's, to ask some of these questions, at first hand, of nature. G. L. G.

4. *Recherche, Captage et Aménagement des Sources Thermo-Minérales.* Origine des eaux Thermo-Minérales; Géologie; Propriétés physiques et chimiques. By L. DE LAUNAY, pp. x, 635, large 8vo. Paris, 1899 (Librairie Polytechnique Baudry et Cie., éditeurs).—M. De Launay has added another to the series of highly valuable practical works prepared by him. The previous volumes on Mineral Deposits, on the Gold Mines of Transvaal, and the Diamonds of South Africa, have been noticed in earlier numbers of this Journal. The present volume discusses thermal springs in different parts of the world. The treatment is thorough and exhaustive. The origin of the springs and their relation to geological and topographical features is first taken up. Then comes a discussion of their chemical composition with the salts and gas in solution, accompanied by numerous analytical tables. Following these are data in regard to the temperature at different springs, ranging, for example, from 81°·5 at Chaudes-Aigues (Cantal) to 27° at Uriage (Isère). The latter half of the work goes more minutely into the account of the individual localities in different parts of the world, giving a large amount of very interesting information about a multitude of places. The work closes with details in regard to the distribution of the hot water to the different establishments, with numerous excellent illustrations.

OBITUARY.

Dr. FRANZ RITTER VON HAUER, the distinguished Austrian geologist, died March 20th, at the age of seventy-seven years.

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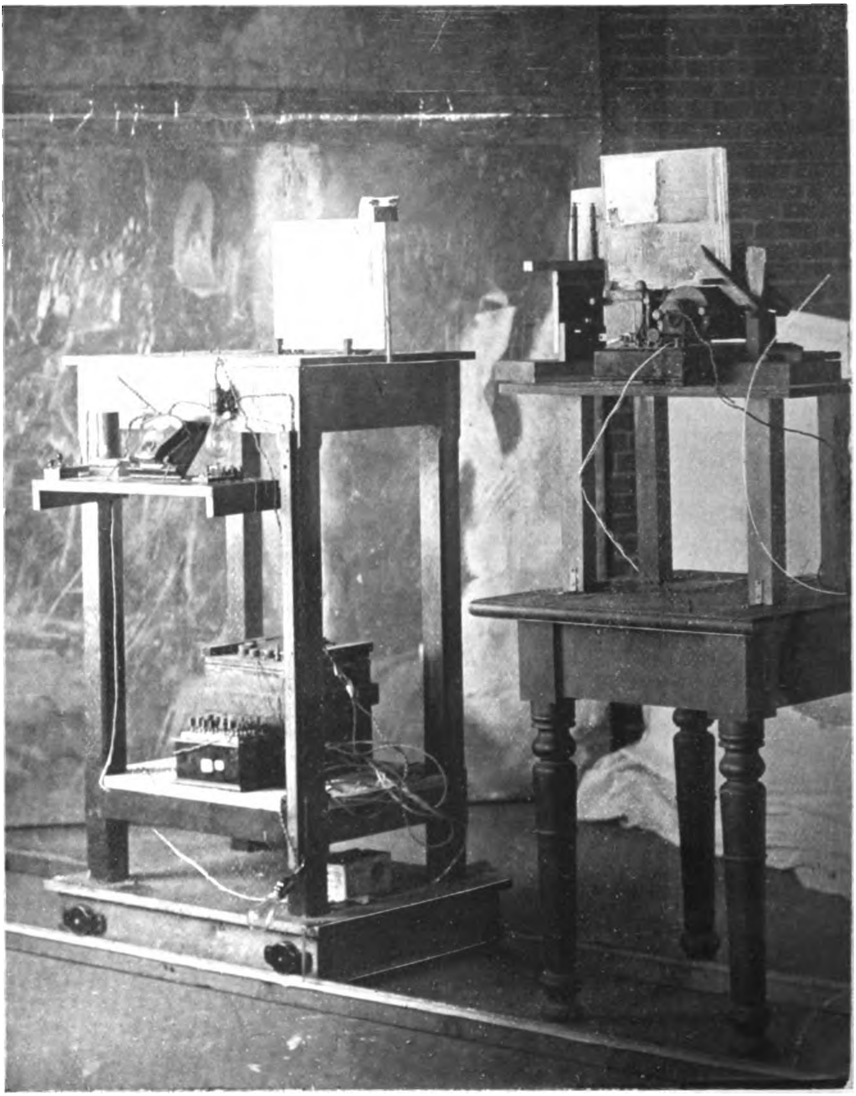

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*Velocity of Electric Waves in Air*; by G. V. MACLEAN. (With Plate I.)

HERTZ determined the wave-length of electric waves in air in one of his experiments to be 9·6 m., with an anti-node 70 cm. behind the reflector. In the case of electric waves along wires he found the rate of propagation to be $2{\cdot}8 \times 10^{10}$ cms. per sec. He further proved, if slow oscillations were used, that the lengths of the electric waves along wires and in air without wires would differ, but if rapid oscillations were employed the lengths of the waves would be the same. The truth of this has been confirmed by J. J. Thomson and Lecher.

E. Sarasin and de la Rive* concluded from their experiments that the wave-lengths determined are independent of the dimensions of the oscillator and vary with the size of the resonator employed. They showed that the rate of propagation of electric waves through air without wires is sensibly the same as that along wires. Thus by using a resonator 26 cms. in diameter the length of the internode along wires was 1·12 and in air between 1·12 and 1·25 m., while a resonator 36 cm. in diameter gave the lengths to be 1·47 m., air between 1·4 and 1·8 ms. respectively. They claimed that the same oscillator gives rise at the same time to waves of different lengths, that the waves sent forth are not simple, but are complexes of an infinite number of different waves, in fact a continuous electrical spectrum is formed, and that the resonator used acts as an analyser picking out from the spectrum those waves whose period is peculiar to itself, and to these alone it responds.

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* Bibliothèque Universelle, Archives des sc. phys. et nat., 3° period, xxiii, No. 2, 1890, p. 113. Also p. 557.

Poincaré* and Bjerknes,† independent of each other, contended that the oscillator and resonator each set up their own vibrations, which are not necessarily related, and that the variation of the wave-length, when different resonators are used with the same oscillator, is not due alone to multiple resonance, as stated by Sarasin and de la Rive, but to the unequal rate of damping of the waves by the resonator and oscillator. If the rate of damping in the resonator is small in comparison with that of the oscillator, then Sarasin and de la Rive's theory holds; if, however, the rate of damping of the resonator is great in comparison with that of the oscillator, Sarasin and de la Rive's theory fails. The length of the internode does not alter when the same oscillator is used with resonators of different sizes, but it varies with the dimensions of the oscillator when the same resonator is employed; the wave-length being the same as is found when a method is employed in which no resonator is needed. "If the rates of damping of the oscillator and resonator are almost the same, the lengths of the waves they produce exercise the same influence upon the length of the internode measured."

Sarasin and de la Rive had also pointed out the necessity of having the oscillator and resonator in tune with each other, and more particularly so was this needful when the waves in air without wires were measured.

In the experiment about to be described, a new method was employed by which the direct determination of the period of the oscillator was found. The oscillator and resonator were tuned by using a special form of self-induction and capacity and balancing them. The resonators used by Hertz, and by the other physicists to whom reference alone has been made, were simple loops of copper wire which acted as the self-induction, while the capacity was two small metal spheres. The oscillators had very large capacities in comparison with those of the resonators.

In our experiment the form and size of oscillator and resonator, as also the dimensions of their self-inductions and capacities, are identical. The resonator here used is a specially devised coherer. Many attempts of late have been made to successfully employ the coherer to measure electric waves. The results have generally been to stamp the coherer as an instrument too capricious for such work. In this connection may be mentioned the work of Professor Murani.‡ He used a

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* Poincaré, Elektricität und Optik, 1891. Archives des sc. phys. et nat, xxv, p. 609, 1891.

† Bjerknes, Wiedemann's Annalen. Band xliv, p. 75, 1891.

‡ Studio della onde stazionarie di Hertz col mezzo di un coherer, del Prof. O. Murani del R. Istituto Lombardo. Milano, 1898.

Marconi coherer and a galvanometer. The readings of his galvanometer, as he moved the coherer farther and farther from the reflector, changed; no zero readings, however, were found and there was no regular increase or decrease in the readings. The following table is taken from his paper:

Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.	Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.
2	12	60	15·4
5	13·4	65	16·0
10	16·2	70	17·0
15	16·3	75	16·5
20	16·4	80	16·2
25	15·5	90	15·8
30	15·8	100	16·2
35	15·5	110	16·5
40	15·8	120	16·0
45	15·5	130	16·3
50	15·5	140	16·4
55	16·0	150	17·2
		200	17·4

His results were submitted to Professor A. Righi, who with Professor Murani, concluded that the coherer was unsuitable for the measurement of stationary electric waves.

Le Royer and Paul von Bërchem* at Geneva, in April of 1894, used a coherer containing iron filings kept between two magnetized needles. Their results showed that the tube they employed had not a wave-length peculiar to itself and that it acted as an analyser and not as a resonator, and that it would serve to measure the electric wave-lengths in air.

The coherer here employed is one reduced to its elements. It might in fact be termed an electro-bolometer, and in general is not more difficult to use than the heat-bolometer.

Two globules of platinum, one mm. in diameter, are attached to the ends of two platinum wires 0·12 mm. in diameter and 1·7 cm. in length. These latter form spirals each of two convolutions about two iron terminals 1·5 mm. in diameter and 4 cm. in length. These terminals run through the center of the two brass caps of a glass tube 8·5 cms. long and 1·5 cms. in diameter. To one of the terminals was connected a mill-head screw, so that the platinum globules could be adjusted to any distance from each other. This constitutes the coherer proper. The glass tube is not exhausted; it serves merely to protect the globules from dust, dampness, or other external interferences. The coherer is placed in circuit with a large Volta-

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* Bibliothèque Univ. Archives de Genève, xxxi, 1894, p. 558.

Pavia battery of peculiar construction giving a steady current, a resistance box in which a resistance of over 100 ohms is always kept, and a Direct Reading Mille-Ampère meter. The current is shunted by a suitable resistance before passing through the coherer.

The capacity and self-induction of the coherer are respectively two sheets of tin foil 14·5 cm. by 14·1 cms. shellacked to the sides of a glass plate 30·4 cms. long, 30·4 cms. wide and 5 cms. thick, and two copper wires 9·62 cms. long, and ·3 mm. in diameter, parallel to each other and distant 5 cms. These two wires had two of their ends soldered to two strips of brush copper which latter made close contact with the tin foil, by means of hard wax; the other ends passed into two small binding posts on the caps of the coherer. The current through the coherer is governed by a key. This constituted the coherer or receiving circuit. All the wires used throughout the whole experiment were well insulated, twisted and kept as far as possible out of the direct course of the electric waves, so that any influence the wires might exert upon the results was reduced to a minimum.

The different parts of the coherer circuit can be seen in the photograph, Plate I.

The platinum globules were first brought into the slightest possible contact by carefully adjusting a micrometer screw. When such a contact had been effected was known by watching the motion of the Mille-Ampère meter needle. Upon causing a train of electric waves to pass the coherer, the resistance of the latter is lessened by the globules moving into closer contact, that is to say the globules are made to cohere. This augmentation of the globules is instantly evidenced by the increased throw of the Mille-Ampère meter needle.

The coherer here employed is the outcome of a great many experiments with Lodge coherers, Marconi coherers or Branly tubes. Tubes containing metal filings of all kinds and of different degrees of fineness, as iron, silver, platinum, copper, zinc, nickel, magnesium, brass, granulated arc carbon with copper, or brass, or iron terminals, either magnetized or non-magnetized, all proved to be unsuitable for measurement of the electric wave-lengths, in not possessing the proper degree of sensitiveness. They all had the common fault of not allowing the Mille-Ampère meter needle to return quickly to its zero reading. Decohering of the coherer in the present form is accomplished almost instantly by the elasticity of the platinum spirals, upon opening the circuit key. No tapping is required as in other kinds of coherers. In fact this form of a coherer alone of all tried gave good working results. Moreover, the above coherer at once shows the manner of action of the ordinary metal filings coherer. The platinum globules are brought into slightest contact, the passage of an electric wave causes the globules to cohere more closely; thus the resistance to the battery current through the coherer is lessened, as is shown by the increased deflection of the needle. The cohering of the metal filings (in this case the two globules) seems to be due to an electrostatic effect produced upon them by the passage over them of the electro-magnetic waves. Further evidence of this will be given later.

Before concluding the description of the coherer, it will be of advantage to give an account of the oscillator circuit and its accessories.

The electric spark which sent forth the trains of electromagnetic waves through the free air between the oscillator and coherer, was given out by a large Ruhmkorff coil in connection with a storage battery of 27 cells in parallel with a voltage of about 55.

The oscillator consisted of two platinum globules 1 mm. in diameter attached to the ends of a platinum spiral making two convolutions about copper terminals, exactly like those in the coherer. This oscillator was placed in the secondary spark gap of the Ruhmkorff coil. The oscillator globules were always kept 4 mms. apart from each other. The same kind and the same amount of capacity and self-induction were used as in the coherer circuit. The coherer and oscillator circuits were thus tuned to one another.

The primary spark-gap of the Ruhmkorff coil was removed to a distant mercury break. The mercury break was of special construction. Three storage cells drove a motor, which in turn caused a plunger to play in and out of a mercury glass cup. On opposite sides of the glass cup were secured a glass tube shoulder, 1 mm. or so above the level of the mercury. To these glass shoulders were attached rubber tubes, one leading from a water tank and the other to a sink. Water was siphoned from the tank through the glass cup, over the surface of the mercury. Thus the surface of the mercury was always clean. A pinch-cock was fixed to the first rubber tube so that the strength of the stream of the running water could be regulated and kept constant. When the stream of water was properly regulated, sparking at the oscillator could be continued for hours at a time, the sparks always being perfectly regular and uniform. Before the addition of the stream of water over the surface of the mercury, the break gave endless trouble, needing attention almost every two or three minutes, but under the conditions adopted it required very little attention. However, care had to be taken to prevent a too free flowing of the water, for otherwise the nature of the sparking at the oscillator was much altered, too much water acting like too little. Wires ran from the break to the Ruhmkorff coil and also to a key at the coherer carriage. Thus from the coherer carriage one could control both the coherer and oscillator circuits.

The various parts of the oscillator circuit are shown in Plate I.

The motor and break were enclosed in a double box, the space between the two boxes being packed with felt. This was done in order to deaden the noise of the motor and primary sparking. Such a proceeding is not essential to the good working of the coherer, but it enables one to detect at once by the ear any variation in the secondary sparking. It thus leaves the eyes free to observe the movements of the Mille-Ampère meter needle. One soon became accustomed to the characteristic crackling sound of the kind of sparks required and accordingly hardly ever needed to look at the oscillator. The sparks produced at the oscillator must be continuous and always the same, otherwise the waves set up will differ from each other and consequently the Mille-Ampère meter needle readings will vary so irregularly as to be absolutely worthless. Sparks of the same nature must therefore be produced at all times during the experiment. This is rendered possible by the employment of the continuous stream of water over the surface of the mercury in the mercury cup of the break.

The coherer and its capacity were mounted upon a stand, carried upon a carriage which could be easily moved along a graduated track. It was possible to make a change in position of the carriage as small as ·25 mm. To the side of the carriage was firmly secured a shelf which supported the keys of the two circuits, the shunt resistance and the Mille-Ampère-meter. The lower part of the carriage held the battery and its resistance box.

If the coherer be placed in any part of the room, it responds to the sparking of the oscillator, but in some positions more strongly than in others. It thus appeared desirable to place the oscillator within a completely closed metal box, with a window in its front side. This proved beneficial, since it caused the waves to be less scattered at the instant of leaving the oscillator, confining them more to that region of the room where the experiment is conducted, than elsewhere. The metal box then acts, as it were, like a megaphone. The front of the box was on hinges and could be left open at pleasure. The inside of the metal box was put into metal connection with the gas pipes of the room. At one end of the room was placed the oscillator, while at the opposite end was fixed a metal reflector which was connected by wires to gas pipes and water pipes. In the free space between the oscillator and reflector moved the coherer carriage. The dimensions of free space between the reflector and oscillator were 12·67 m. in length, 6·15 m. in width and 5·14 m. in height. The nearest wall had five windows, each 1·66 m. by 1·12 m. The reflector was of sheet tin 3·32 m. wide by 4·24 m. high.

The oscillator, the coherer globules and the center of the reflector were always kept in the same horizontal line. The oscillator and coherer were thus 2·25 m. above the floor, 2·89 m. below the ceiling and 1·57 m. from the nearest wall, which ran the full length of the room. By moving the carriage to and fro, the coherer was always in the same horizontal line at any desired distance from the reflector.

The coherer carriage was moved to any distance from the reflector, its globules being put into slightest contact, then the coherer circuit was closed by touching the coherer circuit key and the Mille-Ampère meter needle reading taken. Upon touching the key in the oscillator circuit, sparking at the oscillator began, the electric waves traversing the free space act upon the coherer and at once there is or is not an increased reading given by the Mille-Ampère meter needle. By moving the carriage to different distances from the reflector and repeating the above operations different readings are found. There is seen to be a regular increase and decrease in the Mille-Ampère meter needle readings as the coherer is moved farther and farther from the reflector. At certain places no change in the readings is observed, while at certain other places there is a maximum reading. Thus by means of the coherer we are enabled to locate the nodal and antinodal points of the electric waves, and hence we determine the wave-length. Many precautions had to be taken during the conduction of the experiment. The coherer responds to any (secondary) electric spark, the Mille-Ampère meter readings differing for different kinds of sparks. Not only will the coherer respond to the sparks from the oscillator, but it responds to any other (secondary) spark which at the time may have taken place in any other part of the building or on a distant trolley wire. So sensitive is the coherer, the slightest jarring of the room, such as caused by the slamming of a door or of the walking of persons in the corridor, will be sufficient to very materially confuse the readings. Satisfactory and reliable measurements can only be made when such disturbing causes are not present. Accordingly the night hours were selected in which to carry on the observations. If the mercury in the mercury cup of the break becomes coated, the nature of the secondary spark changes and so the readings under such conditions are not proper. If a too strong current be sent up from the storage battery into the

Ruhmkorff coil, the nature of the secondary sparks change so much that the readings must be disregarded. The greatest care had to be exercised to preserve the equality of the oscillator sparks, throughout the whole of the measurements.

It was further noticed, whenever the key of the oscillator circuit was closed (the coherer key being first closed), there was always a very distinct increase in the Mille-Ampère meter readings even before the sparking at the oscillator began. However, as soon as the sparking at the oscillator commenced, this increased reading was augmented more or less according to the distance of the coherer from the reflector. This peculiar motion of the needle before the sparking begins at the oscillator seems to point to an electrostatic effect upon the coherer globules, due to electric or magnetic causes proceeding from the oscillator and preceding those oscillations which give rise to the stationary waves; whatever the cause may be, it has the effect of lessening the resistance between the coherer globules. This phenomenon would appear to throw some light upon the real cause of the action of a coherer. It shows that the metal particles are attracted nearer to each other and there held in contact by the electrostatic effect produced upon them by the passage of the electric waves. Such an effect being different at different distances from the reflector, and most marked near the oscillator, would very much alter the readings as really given by the wires we are endeavoring to measure. Accordingly this effect had to be eliminated. The elimination was thus accomplished. Upon first closing the coherer circuit and allowing the needle to come to rest and then closing the oscillator circuit, the above described phenomenon having taken place, the sparking at the oscillator was continued for a few seconds, causing the needle to creep up to a maximum reading. Then the oscillator circuit was opened and the coherer circuit was opened and closed four or five times in succession; each time the needle returned to the above determined maximum reading. Next the coherer circuit was opened, the oscillator circuit closed, while the sparking was continued for some time, and finally the coherer circuit was closed. The above determined maximum reading of the needle is in all cases (except when the coherer is at a node) augmented, the amount of this augmentation increasing or decreasing as we move away from the reflector towards the oscillator. It is only such waves as the vigorous and prolonged sparking at the oscillator sets up and maintains that are able to increase the first determined maximum reading. Thus the effects of the above observed phenomenon are obviated, since they are powerless to alter the first-determined maximum reading. Such a precaution demanded a great amount of additional time and patience;

nevertheless it successfully eliminated the disturbance, which was very detrimental to the accuracy of the observed readings of the needle. All the measurements herein given were taken by the above method. The readings thus taken are very small, the highest not exceeding three small divisions of the Mille-Ampère meter scale; but they are otherwise perfectly regular, showing a distinct increase and decrease with change of position of the coherer from the reflector. Readings can be taken with a fair degree of rapidity, when all conditions are favorable; as many as forty having been taken in three hours. Measurements were begun as near the reflector as possible and continued towards the oscillator. The first zero reading was located at 1·1500 m. from the reflector and the first maximum at 2·6290 m. from the reflector. The second zero was found to be at 4·1075 m. and the second maximum at 5·5863 m., while the third zero was at 7·0650 m. from the reflector. We, therefore, have a distance of 1·4790 m. between the first anti-node and node, 1·4785 m. between the first node and second anti-node, 1·4788 m. between the second anti-node and second node and 1·4787 m. between the second node and third anti-node. This gives us a distance of 2·9575 m. between the first and second anti-nodes and also 2·9575 m. between the second and third anti-nodes; that is to say, the half wave-length is 2·9575 m., or the wave-length is 5·915 m. Accordingly there should be a node at ·3290 m. back of the reflector. No results are here recorded of the observations made nearer to the oscillator than a full wave-length. For as one approaches the oscillator in this distance, though the readings show increases and decreases yet no actual zero reading was located. Moreover in this space, the phenomenon above described was very strongly active and difficult to overcome. The measurements below tabulated were all taken in the space at least a wave length distant from the oscillator. The following are the results of nearly 500 observations. The first column gives the distances of the coherer from the reflector, columns two and three give the readings on the Mille-Ampère meter scale for the first maximum reading and the increased reading, while column three shows the increase in the readings due to the passage of the electric waves. Five measurements at least were taken at each point of observation. Owing to the space all the readings occupy, only a few of them are here given. The general nature of the rest of the readings can be seen from the curve (p. 12).

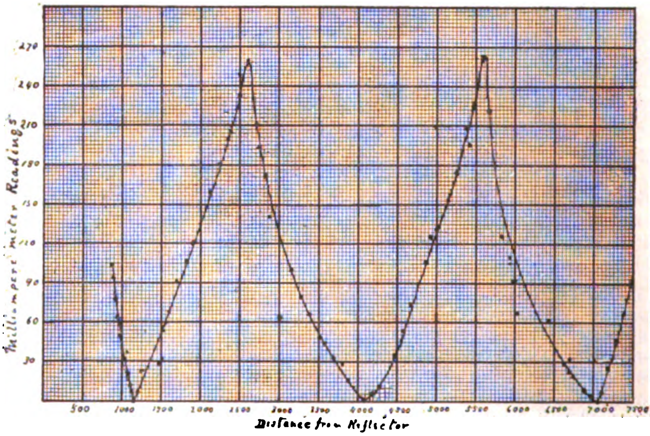
Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
0·9100	8·050	8·125	0·075	mean 0·1035
	7·800	7·900	0.100	
	7·900	8·010	0·110	
	7·550	7·650	0·100	
	8·000	8·100	0·100	
	8·575	8·650	0·075	
	7·700	7 825	0·125	
	8 100	8·225	0·125	
	7 950	8·050	0·100	
	7 900	8·025	0·125	
1·1425	5·750	5·750	0·000	mean 0·0030
	5·750	5·750	0·000	
	5·600	5·605	0·005	
	5 450	5·455	0·005	
	5·775	5·780	0·005	
1·1500	7·725	7·725	0·000	mean (of 20 results) 0·0000
	7·400	7·400	0 000	
First zero or first anti-node	8 450	8·450	0·000	
	7·450	7·450	0·000	
	7·850	7·850	0·000	
1·1705	7 160	7·166	0·006	mean 0·0040
	7·450	7·450	0·000	
	8·565	8·570	0·005	
	8·500	8·509	0 009	
	8 400	8·400	0·000	
1·2500	8·050	8·060	0·010	mean (of 5 results) 0·0100
	8 400	8·410	0·010	
	8·900	8·910	0·010	
1·2710	7·700	7·715	0·015	mean (of 5 results) 0·0130
	8·065	8·075	0 010	
2·2500	The readings are left out, only the means of 5 results given		0·1760	means of 5 results each
2·3450			0 1900	
2·4000			0·2000	
2·4150			0·2050	
2·4745			0 2270	
2·5000			0·2350	
2·6290	8 300	8 566	0·266	mean (of 12 results) 0·2600
	7·400	7·630	0·230	
First node	7·550	7 800	0·250	
	7·500	7·775	0·275	
	7·200	7·475	0·275	
2 6800	The readings are left out, only the means of 5 results are given		0·2250	means of 5 results each
2·7500			0 1930	
2·7960			0·1800	
2·8860			0·1530	
3·0000			0 1350	
3·0660			0·1200	
3·1960			0·1000	
3·2950			0·0780	
3·4000			0·0660	
3·5110			0 0510	
3·6040			0·0440	
3·7040			0·0340	
3·8050			0·0260	
3·9270			0 0120	

Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
4·1075	8·400	8·400	0·000	
	8·750	8 750	0·000	mean (of 15 results) 0·0000
Second zero or second anti-node	8·400	8·400	0·000	
	8·500	8.500	0·000	
	7·600	7·600	0·000	
	7·400	7·400	0·000	
4·1876	The readings are left out, only the means of 5 results are given		0·0050	means of 5 results each
4 2876			0·0120	
4·2880			0·0130	
4·2940			0·0140	
4·3350			0 0150	
4·5056			0·0350	
4 5600			0·0540	
4·6650			0·0740	
4·7250			0·0750	
4·8640			0·1060	
4·9150			0·1140	
5·0000			0·1300	
5·1700			0·1520	
5·2830			0·1720	
5·3285			0·1780	
5·4500			0·1960	
5·5863	8 000	8·233	0·233	
	7·900	8·160	0 260	mean (of 20 results) 0·2620
Second node	8·000	8·280	0·280	
	8·000	8·285	0.285	
	7·400	7.650	0.250	
5·6215	The readings are left out, only the means of 5 results are given		0·2460	means of 5 results each
5·6925			0·2260	
5·8150			0·1250	
6·7000			0·0220	
6 7135			0·0200	
6·7140			0·0170	
6·8850			0·0100	
7·0330			0·0040	
7·0650	7·300	7·300	0·000	
	7·400	7·400	0·000	mean (of 25 results) 0·0000
Third zero or third anti-node	8·850	8 850	0·000	
	8·000	8 000	0·000	
	8·950	8 950	0·000	
	7·000	7·000	0·000	
7·0660	The readings are left out, only the means of 5 results are given		0·0010	means of 5 results each
7·1450			0·0060	
7·1775			0·0250	
7·2945			0·0450	
7·5000			0·0800	

The means of each of these sets of five readings are taken and plotted as a curve, the coördinates of whose points are the distances of the coherer from the reflector and these mean values. The resulting curve is given in fig. 1.

The velocity of the electric waves was determined from the formula $\lambda = VT = 2\pi V\sqrt{LC}$ where λ is the wave-length, L the self-induction, C the capacity, V the velocity and T the time of oscillation of the secondary spark. T was found by the photographic process. The sparks directly given by the oscillator used in the original experiment could not be photographed. They were too small and, moreover, their light was not actinic enough. Sparks given by similar capacity and self-induction but of larger dimensions and cadmium points in place of the platinum globules were photographed. The self-induction here used consisted of two parallel copper wires of the same diameter as were employed in the original experiment, 5 cm. apart and 1051·1 cm. in length. The capacity was the same glass plate with the tin foil sheets four times as large. The time of oscillation of the sparks thus produced was found to be $4{\cdot}12382 \times 10^{-7} = T'$ seconds. It was then assumed, that the formula must still hold good if we cut down the self-induction and capacity, still keeping the copper wires 5 cm. apart. That is to say, if we make our C one-fourth and our L $\frac{1}{100}$th of the L used in the photographic process the time of oscillation of our spark will be $\frac{1}{20}$th of that of the spark photographed. In the original experiment the area of the tin foil was just one-fourth of that on the condenser which formed the capacity for the spark photographed, whereas the length of copper wire was 9·62 cms, being $\frac{9{\cdot}62}{1051{\cdot}1}$ of what was used in the photographic process. Accordingly

1.



the time oscillation of our spark would be $1{\cdot}976 \times 10^{-8}$ secs. This is then the value of T. We have already found λ, the wave-length, to be 591·5 cms. And since $\lambda = VT \therefore V$ the velocity of the electric wave $= \frac{\lambda}{T} = \frac{591{\cdot}5}{1{\cdot}976 \times 10^{-8}} = 2{\cdot}998 \times 10^{10}$ centimeters per second or about 186,365 miles per second.

Professor Trowbridge and Dr. Duane in 1895 found the velocity of electric waves along wires to be $2{\cdot}996 \times 10^{10}$ cms, though the mean of seven of their results gave the velocity to be $3{\cdot}0024 \times 10^{10}$ cms. per second. To make sure the coherer and oscillator were in tune with each other, the capacity of the oscillator was altered by doubling the area of the tin foil sheets on the glass plate. Sparking at the oscillator was again begun and readings taken whereby it was seen the positions of the original nodal and anti-nodal points were changed. The same thing took place upon altering the self-induction. Also separately the self-induction and capacity of the coherer were altered, with a similar change in the position of the original nodal and anti-nodal points. When the wave-length had been determined it seemed desirable to test the truth of the theory of Poincaré and Bjerknes. It is a known fact in the photography of electric oscillation, that it is possible to damp out all the oscillations except the fundamental by replacing part of the self-induction by a self-induction having a higher resistance. As, for example, interchanging a length of copper wire by the same length of graphite. Accordingly a cylinder of graphite 5 cms. long was ground down till it had the same diameter of the copper wire it was to replace. The ends of this rod of graphite were next electroplated with copper. Five cms. of one of the copper wires forming the self-induction of the coherer were cut out and replaced by soldering in the prepared graphite. The coherer and oscillator circuits had now the same capacity and self-induction as before, only the resistance of the self-induction of the coherer circuit had been increased. The resistance of the graphite was 12 ohms. Work was now undertaken under these new conditions, with the result that the fifty observations thus made were identical with those taken under the original conditions. The following table gives the measurement taken when the graphite was in the circuit.

Distance in cms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
1·1500	8·100	8·100	0·000	mean 0·0000
	8·550	8·550	0·000	
	8·450	8·450	0·000	
	6·450	6·450	0·000	
	8·250	8·250	0·000	
2·6290	8·600	8·825	0·225	mean 0·2600
	8·000	8·250	0·250	
	7·600	7·850	0·250	
	7·800	8·100	0.300	
	8·550	8·825	0·275	
2·7960	8·150	8·325	0·175	mean 0·1800
	7·400	7·565	0·165	
	7·450	7·650	0·200	
	6·475	6·650	0·175	
	8·000	8·185	0·185	
3·1960	7·800	7·900	0·100	mean 0·1000
	7·750	7·850	0·100	
	7·250	7·400	0·125	
	8·425	8·500	0·075	
	8·400	8·500	0·100	
4·1075	8·750	8·750	0·000	mean 0·0000
	8·350	8·350	0·000	
	7·100	7·100	0·000	
	8·300	8·300	0·000	
	8·400	8·400	0·000	
3·4000	8·800	8·850	0·050	mean 0·0660
	8·425	8·500	0·075	
	8·400	8·466	0·066	
	8·500	8·575	0·075	
	8·100	8·165	0·065	
4·5056	8·150	8·175	0·025	mean 0·0375
	7·750	7·800	0·050	
	8·350	8·400	0·050	
	8·575	8·600	0·025	
	8·300	8·350 ?	0·050 ?	
	7·835	7·860	0·025	
5·5863	8·400	8·625	0·225	mean 0·2620
	8·450	8·700	0·250	
	8·150	8·450	0·300	
	8·500	8·750	0·250	
	8·450	8·735	0·285	
6·6670	8·250	8·300	0·050	mean 0·0350
	8·400	8·425	0·025	
	8·500	8·525	0·025	
	8·100	8·150	0·050	
	8·550	8·575	0·025	
7·0650	8·950	8·950	0·000	mean 0·0000
	8·800	8·800	0·000	
	8·650	8·650	0·000	
	8·600	8·600	0·000	
	8·800	8·800	0·000	
	7·350	7·350	0·000	
	7·450	7·450	0·000	
	7·600	7·600	0·000	
	7·845	7·845	0·000	
	8·000	8·000	0·000	

This latter experiment shows that the wave-length we have measured was that of the fundamental wave. And, moreover, that by the use of this particular coherer or the electro bolometer, the balancing of the self-inductions and capacities and by our method of operating the oscillator, all the electric waves in the number of different waves proceeding from the Ruhmkorff coil, except the fundamental, had been completely damped. If such had not been the case, it is very evident the measurement so taken would not have been identical with those first observed.

The experiment was pushed further. The new self-induction (graphite) of the coherer circuit being retained, the capacity of the oscillator circuit was made double of what it was in the original case and, therefore, double of that now in the coherer circuit. At those points where the original readings indicated nodes and anti-nodes the readings were now changed. The following table shows some of the changes.

The new self-induction in the coherer circuit and the original capacity in the oscillator circuit.		The new self-induction in the coherer circuit and the capacity in the oscillator circuit, doubled.
Distance in ms. of the coherer from the reflector.	Difference between the maximum and increased maximum readings of the m-a-m.	Difference between the maximum and increased maximum readings of the m-a-m.
1·1500	0·000	0·075
2·6288	0·260	0·275
4·1075	0·000	0·150
5·5863	0·262	0·250
7·0650	0·000	0·081
	(average of 5 readings)	(average of 5 readings)

Similar changes took place at other points.

Next the capacity of the coherer circuit was altered and as a consequence, at those points where the original readings were taken, the readings now were different. Finally the capacity (i. e. the tinfoil plates) of the coherer circuit was left out entirely and so also was the self-induction, for at this stage of the experiment the graphite broke. The readings were now of all sorts, the needle moving very capriciously, whenever the sparking began or continued at the oscillator. No regular increase and decrease in the readings could be determined, as the coherer was moved farther and farther from the reflector. At one time the needle would be deflected four or five whole divisions of the Mille-Ampère meter scale while in the next second, at the same place, there would be only a displacement of the needle of ·2 or ·3 of a division in the forward direction or else a deflection in the opposite direction, and even at times the needle trembled as if acted upon by almost equally opposing influences. These irregular motions of the needle made a great contrast with the regular motions when the coherer and oscillator were in tune. This experiment confirms the truth of the damping theory of Poincaré and Bjerknes.

Sarasin and de la Rive's theory of a multiplicity of waves of different amplitudes originating at the same oscillator was substantiated by the erratic readings obtained when the coherer proper alone was employed. In fact the truth of their theory was readily seen when the ordinary metal filings coherer or Branly tube was used, since the irregularity of the readings was evidently such as would be produced by quickly succeeding waves of different kinds acting upon the tube. The point which might be the position of a node due to one wave would be the anti-node or at least not always the node due to the next following wave.

I desire here to express my gratitude to Professor Trowbridge for his valuable suggestions, his assistance and his very great kindness in placing at my disposal the resources of the Physical Laboratory in order to have this experiment carried to a successful completion.

Jefferson Physical Laboratory, Harvard University,
Cambridge, Mass., April, 1899.

Art. II.—*A Spiral Fulgurite from Wisconsin;* by William H. Hobbs.

There has recently been presented to the geological collection of the University of Wisconsin a lightning tube or fulgurite which has considerable interest because of its shape—a perfect dextro-rotary helix. The specimen is the gift of Mr. G. H. Kruschke, town clerk of the town of Cutler, Wisconsin, who has furnished me with the data for the following description of the manner of its discovery.

The fulgurite was discovered in October, 1897, by Frank de Lap, Mr. Kruschke's son-in-law, while digging a cellar on the southeast quarter of the northeast quarter of Sec. 20, T. 18, R. 2 E., Town of Cutler, Juneau County, Wisconsin. It was imbedded in a sand knoll about ten feet high, at a distance of five feet below the surface. A house has since been built upon the spot.

A sample of the sand in which the tube was found has been kindly furnished by Mr. Kruschke, and proves on examination to be a fairly clean sand, of a light brown color, largely composed of translucent quartz grains which average about $\frac{1}{64}$th of an inch in diameter. The coloring matter appears to be ferric oxide. The tube itself is about as thick as a man's thumb, and over five inches long. When found it was about three inches longer, but Mr. Kruschke reports that a piece was accidentally broken off and lost. Examination of the broken end shows that the fulgurite is composed of a dull gray slaggy mass, filled with larger and smaller cavities exactly like those observed in porous natural slags. There are a few dark specks surrounded by stains of iron oxide. Somewhat excentrically located in this end section is a cavity of irregular cross-section which appears to extend into the fulgurite as a more or less continuous tube, but is so bent and locally contracted that it is impossible to follow it for any distance. Its average diameter is about $\frac{3}{16}$th of an inch, but it is partly filled by blister-like eruptions which protrude from its walls. One of these blisters which is broken open has walls as thin as paper.

The other end of the fulgurite has not been broken in any way but forms four irregular horn-like projections (*a-a-a* in the left of fig. 1). The channel (it cannot be asserted that this is continuous with the one observed at the other end) emerges at one side of the fulgurite (*a*, in right hand portion of fig. 1) with only a thin wall less than a millimeter in thickness on the outer side.

The surface of the fulgurite is very irregular, being traversed by corrugations whose greatest extension is in the direction of the longer axis of the fulgurite, though they exhibit some tendency to wrap themselves around it in a dextro-rotary manner. These corrugations appear to be, for the most part, thin-walled tubes (*b*, at the left in fig. 1) which are not now continuous passages, but are so distorted and contracted locally as to suggest that they have suffered collapse since their formation.

1.

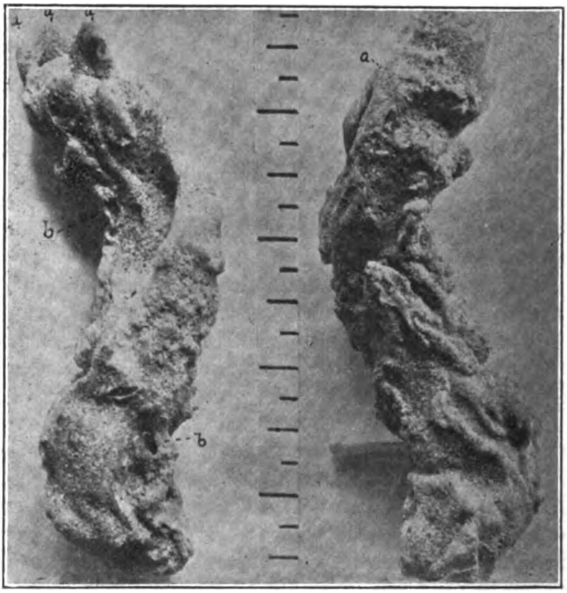


Fig. 1. Spiral fulgurite from Cutler, Wisconsin, showing opposite sides. The units in the scale are inches. *a*, *a*, *a*, in the figure at the left, horn-like protuberances terminating the fulgurite. *b* of the same portion of the figure, corrugations broken open and exhibiting thin-walled tubes. *a* in figure at the right, point of emergence of main channel (hidden in the view).

Over the entire outer surface of the fulgurite are grains of sand which show varying degrees of former fusion. Those which have been completely fused are opaque and white, and are firmly cemented to the glass of the tube. The others adhere less firmly and where distributed abundantly appear brown, as in the sample of loose sand from the locality. The photographs shown in fig. 1 exhibit opposite sides of the fulgurite and indicate, as well as any photographs are likely to do, its perfectly helical form. The only fulgurite known to me which shows any approach to this shape is that from Waterville, Maine, described by Bayley,* which has marked corrugations that wind about the axis of the fulgurite in the form of a dextro-rotary helix.

The fact that the Waterville and Cutler fulgurites show each a spiral twist of the same type is sufficient evidence that the structure is not an accidental one, but one to be explained by the conditions of the lightning discharge, which doubtless followed a spiral course through the sand. Professor R. W. Wood, of the Physical Department of the University of Wisconsin, has suggested to me that this may be explained in some way by the influence of the earth's magnetic field upon the discharge. There is at least a possibility that there may be some analogy between the experiments of Hittorf† with electric

2.

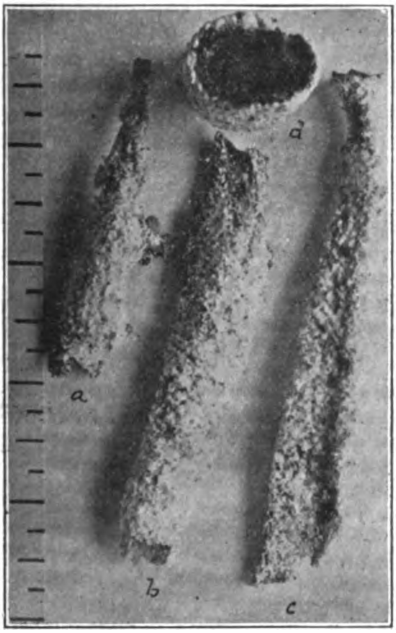


FIG. 2. Artificial fulgurites made by Prof. Wood. The units in the scale are inches. *a* is a tube with branch-like protuberance at the side. *b* is a tube of nearly symmetrical cross-section. *c* is a tube with marked corrugation extending along one side. *d* exhibits the cross-section of a large tube.

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* A Fulgurite from Waterville, Maine, by W. S. Bayley, this Journal (3), 1892, xliii, p. 327.

† J. J. Thomson, Recent Researches in Electricity and Magnetism. Oxford, 1893, p. 134.

discharges in a magnetic field, and the lightning discharge. Hittorf found that in the case of negative discharge in a direction nearly parallel to a line of force that the spark takes the form of a dextro-rotary spiral and wraps itself about the line of force. It hardly seems possible that the earth's field would be sufficiently strong to effect such a change in the course of the lightning, and, moreover, the return discharge would be of an opposite character, and should produce a spiral of the opposite kind unless the initial discharge controls the form of the sand tube. The above is, therefore, offered only as a suggestion and not in any sense as an adequate explanation.

I do not remember to have seen any description of artificial fulgurites. Professor Wood, on being shown the Cutler fulgurite, expressed the belief that he could make some of the ordinary kind. Within a half hour he had produced the tubes which are shown in fig. 2, by immersing carbon electrodes in a bath of sand and passing the current from an ordinary arc circuit through them. In *a* of the figure is seen a fulgurite having a hollow protuberance on one side—really a branch of the tube; *b* is a tube of fairly symmetrical cross section; the tube *c* has a marked corrugation extending along one side, and shows perhaps a slight trace of spiral curving; while *d* (shown in cross section) indicates how large fulgurites may be made by this simple method. I am indebted to Professor Wood for permission to publish a photograph of these artificial fulgurites.

University of Wisconsin.

Art. III.—*On the Chemical Composition of Parisite and a new occurrence of it in Ravalli Co., Montana;* by S. L. Penfield and C. H. Warren.

Recently Mr. Lazard Cahn of New York sent to the Mineralogical Laboratory of the Sheffield Scientific School for identification, several specimens from Montana, showing crystals of an unusual appearance. These proved to be the rare mineral parisite, hitherto observed only in small amount at the original locality, the emerald mines of the Muso Valley, United States of Columbia; sparingly at Ober Arö, Langesundfiord, Norway;* and quite recently the mineral has been found at Narsásuk in Southern Greenland. A brief note on its occurrence at the latter locality was made by Gust. Flink in the report of a trip made there during the summer of 1897.

Not only does a new occurrence of parisite and the peculiar habit of the crystals deserve notice, but the chemical composition of the mineral has never been determined with certainty, and, therefore, analyses have been made for the purpose of determining this important character. It is with pleasure that we express to Mr. Cahn our thanks for a generous supply of the material from Montana for analysis.

The parisite crystals from Montana are supposed to have come from near Pyrites, Ravalli County, and occur in a fine-grained, loosely coherent, white material, which can be readily crushed to a powder with the finger nail. The matrix consists essentially of silica, alumina, calcium and a little alkali, and has the appearance of a decomposed rhyolite or trachyte, but its exact nature has not been more definitely determined. Through this white material crystals of pyrite and parisite are scattered, generally isolated, but at times the parisite has grown over and partly or completely surrounded the pyrite crystals. The pyrite is crystallized in pyritohedrons modified by small faces of the cube and octahedron, and the crystals vary in size from microscopic up to 3^{mm} in diameter. The average size of the parisite crystals is about 1^{mm} in diameter by 10^{mm} in length. They are quite numerous, so that from four to ten individuals may be seen on a surface of ten square centimeters of the matrix. The habit which they generally present is that of a horizontally striated hexagonal shaft, made up of steep pyramids in oscillatory combination and terminated at the ends by distinct, somewhat enlarged pyramids. The accompanying figure, which represents a portion of the shaft and one termination, gives a fair idea of the development of the crystals. The faces which are most prominent in forming the shaft are those of the pyramid *o* ($20\bar{2}1$) in oscillatory combination. Measurements over the reëntrant and salient angles could be made with the reflecting goniometer and are given in an accompanying table. Some of the edges of the pyramid *o* are truncated by a pyramid of the second order *s* (11$\bar{2}$1), also in oscillatory combination, but, as shown in the figure, this form generally is not continuous throughout the whole length of the shaft nor is it present on all the edges. The pyramid which finally terminates the crystals is *r* (20$\bar{2}$3). This is generally quite distinct, although its middle edges are somewhat rounded by a system of fine horizontal striations. The prism of the second order *a* (11$\bar{2}$0), represented in the figure, is always small and frequently wanting. The prism of the first order, *m* (10$\bar{1}$0), was not observed as a distinct face, although the oscillatory combination of the upper and lower pyramidal faces often gave rise to striated, rounded, surfaces which approximate in position to the faces of this prism. Occasionally the shafts taper to a point without the enlarged pyramid. Of the forms observed, *a* (11$\bar{2}$0), *r* (20$\bar{2}$3), *o* (20$\bar{2}$1), *s* (11$\bar{2}$1) and *m*? (10$\bar{1}$0), the prism *a* is new. The angles which were measured are given below, together with the values calculated from the vertical axis established by Des Cloizeaux,[*] $c = 3{\cdot}2891$.

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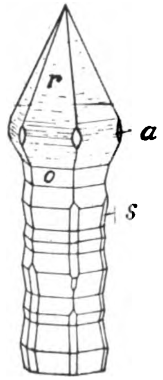
* Brögger, Zeitschr. Kr., xvi, 650, 1890.



	Measured.	Calculated.
$a \wedge a = 11\bar{2}0 \wedge \bar{1}2\bar{1}0 =$	59° 54′	60° 00′
$r \wedge r = 20\bar{2}3 \wedge 02\bar{2}3 =$	55 25	55 25½
$r \wedge r = 20\bar{2}3 \wedge \bar{2}023 =$	137 22	136 54
$s \wedge s = 11\bar{2}1 \wedge 11\bar{2}\bar{1} =$	17 23	17 18
$o \wedge o = 20\bar{2}1 \wedge 20\bar{2}\bar{1} =$	13 10	14 00

For the chemical analysis the best material that could be obtained was secured by picking out the crystals from the matrix by hand, and rubbing them between the fingers to remove any loosely adhering material. The crystals enclosed, as has been said, a little pyrite and were not very firm, consequently some siliceous material was deposited in the cracks. These impurities amount to about six per cent. The material was of a nearly uniform yellowish brown color.

The method of analysis was as follows: Carbon dioxide was obtained by dissolving the mineral in hydrochloric acid and collecting the gas evolved in weighed potash bulbs. For fluorine, another portion of material was fused with sodium carbonate and a weighed amount of silica, and the fluorine separated and estimated by the Berzelius method as modified by Penfield and Minor.[†] The earths were separated from calcium by repeated precipitations with ammonia, and they were then converted into oxalates, ignited, and weighed as oxides. The amount of cerium oxide, Ce_2O_3, was estimated by decomposing the ignited oxides (CeO_2, La_2O_3 and Di_2O_3) with sulphuric acid, to which some oxalic acid was added, and weighing the carbon dioxide liberated by the higher oxide of cerium, according to the equation, $2CeO_2+H_2C_2O_4=Ce_2O_3+2CO_2+H_2O$. The joint molecular weight of the cerium, lanthanum, and didymium oxides $(Ce, La, Di)_2O_3$ was estimated by converting a weighed quantity of the oxides into sulphates and was found to be 328·2. The results of the analyses are given beyond.

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[*] Min., ii, p. 162, 1874.

[†] This Journal, III, xlvii, p. 387, 1894.

As the considerable amount of impurities in the Montana parisite rendered the calculation of the formula somewhat uncertain, an analysis of the mineral from Muso Valley was also made. Exceptionally pure material for this analysis was obtained from a fragment of a large crystal in the Brush collection. In this analysis it was found that the full amount of fluorine was not obtained by a single fusion with sodium carbonate and silica, and soaking out with water. By saving the residues and fusing them a second time with sodium carbonate and a slight addition of silica, about 0·5 per cent of fluorine was obtained. This precaution was not taken in the analysis of the Montana mineral and consequently the ratio of the fluorine in that analysis is a little low. The joint molecular weight of the cerium, lanthanum and didymium oxides was found to be 328·4. The results of the analyses are given below, together with the analysis by Damour and Deville* of the parisite from Muso.

	I. Warren. Montana.	Ratio.	II. Warren. Muso.	Ratio.	III. Damour and Deville. Muso.	Ratio.
Specific gravity,	4·128		4·302		4·358	
CO_2	22·93	·521	24·22	·550	23·48	·533
F	5·90	·310	6·82	·359	5·55	·292
Ce_2O_3	26·14	·166	30·67	·183	44·21	·187
$(La, Di)_2O_3$	28·46		29·74		18·00	
CaO	10·98	·196	10·70	·191	10·10	·180
Fe_2O_3 (pyrite ?).	·80		·20		101·34	
Na_2O	·69		·20		0= 2F=2·34	
K_2O	·19		.10		99·00	
H_2O	·26		102·65			
Gangue by difference.	6·13		0=2F=2·87			
	102·48		99·78			
0 = 2F	2·48					
	100·00					

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* C. R., lix, p. 270, 1864.

The ratios derived from the foregoing analyses are as follows:

	CO_2	:	F	:	$(Ce, La, Di)_2O_3$	:	CaO								
I.	·521	:	·310	:	·166	:	·196	=	3·00	:	1·79	:	0·96	:	1·13
II.	·550	:	·359	:	·183	:	·191	=	3·00	:	1·96	:	1·01	:	1·04
III.	·533	:	·292	:	·187	:	·180	=	3·00	:	1·65	:	1·05	:	1·01

The new analysis of the exceptionally pure material from Muso Valley gives a ratio approximating very close to 3:2:1:1. The material from Montana is not so pure, consequently the ratio is less satisfactory. The fluorine in the mineral doubtless caused some of the gangue material to go into solution, thus causing the calcium to be a little high; while the fluorine is evidently low, because, as previously stated, the precaution was not taken to repeat the fusion with sodium carbonate and silica in estimating that constituent. The ratio obtained by Damour and Deville agrees with those obtained from the new analyses except as regards fluorine. It is believed, however, that their method of estimating fluorine is open to criticism, since they made no direct determination of this element but, assuming that on dissolving the mineral in very dilute hydrochloric acid the fluorine separated out completely as the fluorides of calcium and cerium, they ascertained the weight of these fluorides, and considered fluorine as equal to the difference between this weight and that of the calcium and cerium derived from an analysis of the insoluble residue.

Excepting the defects in the analyses, evidently due to failures in estimating fluorine correctly, the ratios derived from the three analyses indicate conclusively that CO_2, F, $(Ce, La, Di)_2O_3$ and CaO are united in the proportion of 3:2:1:1. Representing the trivalent metals of the cerium group collectively by R, it is probable that fluorine is directly united with them to form a bivalent radical (RF), and that parisite is a double carbonate, $2(RF)CO_3 + CaCO_3$, or $(RF)_2Ca(CO_3)_3$.

As far as the proportions of the different constituents is concerned, either of the foregoing expressions is equivalent to the formula proposed by Groth[†] $(CaF)'(CeF)''Ce(CO_3)_3$. Groth based his formula upon the single analysis of Damour and Deville, previously cited, and was correct in assuming that the deficiency in fluorine was due to a failure to estimate that constituent correctly. It seems to us more reasonable to consider the fluorine as playing a single role, united with the Ce, La, and Di metals to form a bivalent radical (RF), than to adopt the formula of Groth where fluorine plays a double role, united with calcium to form a univalent radical (CaF) and with cerium to form a bivalent radical (CeF).

[*] Tabellarische Uebersicht der Mineralien, 1898, p 61.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1899.

ART. IV.—*The Estimation of Iron in the Ferric State by Reduction with Sodium Thiosulphate and Titration with Iodine;* by JOHN T. NORTON, JR.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIII.]

THE action of sodium thiosulphate on ferric iron has long been known and depends upon the following reaction:

$$2FeCl_3 + 2Na_2S_2O_3 = 2FeCl_2 + Na_2S_4O_6 + 2NaCl.$$

As early as 1859 Sherer* proposed a method for the estimation of ferric iron depending on the above reaction. Sherer's method of procedure was to act upon a solution of ferric chloride with sodium thiosulphate until the purple color produced by the interaction of these two salts just vanished. Mohr's† experimental tests of this process were not successful. A year or two later Kremer and Landolt,‡ after a careful investigation of Sherer's process, recommended it with the modification that any free hydrochloric acid present should be neutralized by sodium acetate until the solution assumed a red color, just enough hydrochloric acid added to destroy this red color, and sodium thiosulphate run into the solution in slight excess. When the liquid became perfectly colorless and gave no reaction for ferric iron with potassium sulphocyanide, the excess of sodium thiosulphate was titrated back with iodine and starch. The authors also state that the ferric iron should not be present in concentrated solution. Very good results were claimed for this process, but it apparently gained but slight recognition.

Oudemanns,§ who was the next to study the action of ferric iron and sodium thiosulphate, claimed that the addition of a small quantity of cupric salt to the iron solution hastened the reducing action of the sodium thiosulphate. Mohr,‖ however, condemned this method also as unreliable, both because the sodium thiosulphate acted upon the copper as well as the iron and also because the potassium sulphocyanide, added as an indicator of the completeness of the reduction, produced a precipitate of cupric sulphocyanide which interfered with the reaction. In a second paper Oudemanns¶ reiterated his former statement as to the accuracy of his method but advised the use of a smaller quantity of the cupric salt. An improvement on Oudemanns' process was proposed by Haswell,** who mixed the moderately acid solution of ferric chloride in the presence of a cupric salt with a few drops of sodium salicylate and then reduced with sodium thiosulphate previously standardized upon a known quantity of iron by the same process and estimated the excess by potassium dichromate. Bruel* modified this process by operating without the copper solution, relying merely on the discharge of the violet color in a boiling solution by sodium thiosulphate standardized on a ferric solution of known strength.

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* Gelehrte Anzeigen der König. Bayrisch. Acad. vom Aug. 31, 1859.

† Anal. d. Chem. u. Pharm., cxiii, 260.

‡ Zeitschr. f. Anal. Chem., i, 214.

§ Zeitschr. f. Anal. Chem., vi, 129.

‖ Titrirmethode

¶ Zeitschr. f. Anal. Chem., ix, 362.

** Repertorium der Analytischen Chem., i, 179.

Although considerable work has been done on the reaction between ferric iron and sodium thiosulphate, no process depending upon this reaction has obtained acceptance. In view, therefore, of previous work on the action of hydrochloric acid upon sodium thiosulphate† and with the idea that a careful control of the dilution and quantity of acid present might greatly better the accuracy of the method, it has seemed to me to be desirable to study this process again in detail.

The ferric oxide employed in the experiments was prepared with great care by the ignition of ferrous oxalate obtained by acting with oxalic acid on pure ammonium ferrous sulphate. To ascertain, however, if this oxide contained any impurity, about 0·5 of a grm. was put into a porcelain boat and submitted to the action of a current of hydrochloric acid gas and chlorine at a temperature of about 280° C. (according to a process recently described from this laboratory‡) until all the ferric salt is volatilized in the form of ferric chloride. A residue of 0·0010 grm. for every 0·5 of a grm. of the oxide was found, and this correction, small for the amounts generally used, has been applied in the following determinations. The sodium thiosulphate used was taken in nearly $\frac{n}{10}$ solution and was standardized against an approximately decinormal solution of iodine which had been determined by comparison with decinormal arsenious acid made from carefully resublimed arsenious oxide.

In those experiments which deal with amounts of ferric oxide not exceeding 0·2 of a grm., measured portions of a solution of ferric chloride made of known strength by dissolving about 2 grms. of the pure carefully weighed ferric oxide in 20^{cm^3} of strong hydrochloric acid and diluting to one liter, were drawn from a burette. In the case of the larger quantities of ferric oxide the salt was weighed out, dissolved in hydrochloric acid and brought to the required dilution. The ferric chloride, either drawn from the burette or prepared directly from the weighed oxide, was diluted with water, a drop of potassium sulphocyanide added to serve as an indicator and an excess of sodium thiosulphate was run in until, after standing for a few minutes, the solution became perfectly colorless, and the excess of sodium thiosulphate was then titrated back with decinormal iodine after the addition of starch.

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* Compt. Rendus, xcvii, 954.

† This Journal, vol. vii, 287.

‡ Gooch and Havens, this Journal,

Several sources of error are, plainly, possible in the process: incompleteness in the reduction of the ferric salt; decomposition of the thiosulphate by the acid, resulting in the subsequent over-run of iodine; the possible tendency of the ferric salt under concentration to oxidize the thiosulphate to the condition of the sulphate rather than to that of the tetrathionate; and finally the oxidizing action of the air, which may tend to keep up progressive oxidation of the iron salt and excessive expenditures of thiosulphate. The first three sources of difficulty tend to produce errors of deficiency; the fourth an error of excess.

The first step in the experimental study of the process was to determine the effect of varying dilution upon the estimation of a given quantity of iron reduced by sodium thiosulphate, taken in practically uniform excess above the amount theoretically required, in the presence of 1^{cm^3} of hydrochloric acid.

TABLE I.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3	$Na_2S_2O_3$ in excess. cm^3.	Fe_2O_3 found. grms.	Error. grms.
1.	·1000	·0998	100	1	18·08	·0957	·0041 —
2.	·1000	·0998	200	1	20	·0966	·0032 —
3.	·1000	·0998	300	1	17·56	·0995	·0003 —
4.	·1000	·0998	400	1	17·16	·0998	·0000
5.	·1000	·0998	600	1	17·76	·0996	·0002 —
6.	·1000	·0998	800	1	17·65	·0993	·0005 —
7.	·1000	·0998	1000	1	18·02	·0988	·0010 —
8.	·1000	·0998	1200	1	17·95	·0977	·0021 —
9.	·1000	·0998	1400	1	17·99	·0965	·0033 —
10.	.1000	·0998	1600	1	18·01	·0947	·0051 —
11.	·2001	·1997	400	2	27·05	·2029	·0032 +
12.	·2001	·1997	800	2	15·95	·1998	·0001 +
13.	·4998	·4988	1000	2	22·36	·5104	·0126 +
14.	·5051	·5041	1800	4	15·27	·5026	·0017 —
15.	·4002	·3994	1500	4	27·29	·3996	·0002 +
16.	·7502	·7487	1000	1	9·73	·7572	·0085 +
17.	·7029	·7015	2000	4	12·67	·7004	·0011 —

This table shows plainly that with quantities of ferric oxide present up to 0·1 grm. the dilution can vary from 400^{cm^3} to 1000^{cm^3} for each cm^3 of strong hydrochloric acid and still give excellent results. At a dilution greater than 1000^{cm^3} the action of the thiosulphate is evidently incomplete, and at a smaller dilution than 400^{cm^3} the decomposing action of the acid on the thiosulphate becomes noticeable. When larger quantities of iron oxide are dealt with, it appears that the dilution ought to be increased proportionally with the quantity of ferric oxide present as well as with that of the acid. This is illustrated in experiments 9–15 of the table. On this account it seems necessary, assuming that the quantity of acid present is always kept within the maximum strength mentioned, 1^{cm^3} to 400^{cm^3}, to regulate the dilution from the approximate quantity of the iron so that not less than 400^{cm^3} of water shall be used to every 0·1 grm. of iron oxide present. Under properly regulated conditions of dilution as regards acid and the iron salt, the reduction is completed in from five to ten minutes.

Great excesses of acid, however, contrary to the statement of Kremer,* retard the reduction greatly, and, in spite of the tendency of the thiosulphate to decomposition and the production of errors of deficiency under such circumstances, plus errors due to partial oxidation come to light. This fact appears in the following table, which records the results of processes lasting many hours.

TABLE II.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm³.	HCl. cm³.	$Na_2S_2O_3$ in excess. cm³.	Fe_2O_3 found. grms.	Error. grms.
18.	·5012	·5002	1700	10	25·99	5308	·0306 +
19.	·7512	·7497	1200	15	57·8	7685	·0188 +
20.	·7520	·7505	2000	15	56·4	7983	·0478 +
21.	·7520	·7505	1700	15	27·2	·7627	·0122 +

As to the temperature at which the reduction should be made, my experience, contrary to that of Kremer, goes to show that no elevation above atmospheric conditions is necessary; under the conditions of acidity and dilution laid down, the process of reduction is complete within ten minutes after the introduction of the thiosulphate; moreover, former experience† shows clearly the danger of submitting mixtures of sodium thiosulphate and acid to temperatures much above the ordinary. On the other hand, artificial reduction of temperature tends to retard the action to an impossible degree. Thus, in an experiment it took five minutes to reduce 0·0500 of ferric oxide at 21° C. completely at a dilution of 200^{cm^3} and in the presence of $\frac{1}{2}^{\text{cm}^3}$ of hydrochloric acid; under conditions otherwise precisely similar excepting that the temperature was lowered to 0° C., the action lingered forty-five minutes.

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* Zeit. f. Anal. Chem., i, 214.

† This Journal, vol. vii, 287.

Lastly, the question as to the excess of thiosulphate necessary to complete the reduction within a reasonable time must be considered. In nearly all previously recorded experiments the excess of thiosulphate was not less than 15^{cm^3} of the $\frac{n}{10}$ solution. The following table shows the effect of diminishing this excess.

TABLE III.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm³.	HCl. cm³.	$Na_2S_2O_3$ in excess. cm³.	Fe_2O_3 found. grms.	Error. grms.
22.	·0250	·0250	400	¼	12·2	·0241	·0009—
23.	·0500	·0499	400	½	12·2	·0495	·0004—
24.	·0500	·0499	400	½	13·66	·0493	·0006—
25.	·1000	·0998	400	1	7·31	·0984	·0014—
26.	·1000	·0998	400	1	7·63	·0972	·0026—
27.	·1001	·0999	400	1	12·88	·1007	·0008+
28.	·1498	·1495	600	1½	11·97	·1475	·0020—
29.	·1996	·1992	800	2	12·43	·1980	·0012—

From the above experiments taken in connection with those of Table I it is clear that there should always be present an excess of at least 15^{cm^3} of the $\frac{n}{10}$ solution of sodium thiosulphate. If the quantity of hydrochloric acid is kept very low there is no reason why this excess of thiosulphate could not be considerable without producing any disturbing effect. Practically, however, the presence of an excess between the limits of 15^{cm^3} and 35^{cm^3} of the $\frac{n}{10}$ solution has been found to give the most satisfactory results.

To recapitulate then, it has been shown that the dilution must be at least 400^{cm^3} for each ·1 of a grm. of iron oxide present, that the quantity of acid should never exceed 1^{cm^3} of the strong acid to each 400^{cm^3} of water, that the time of reduction must be short to avoid progressive oxidation, that the temperature of the solution should be kept at the normal temperature of the atmosphere, and finally that the excess of sodium thiosulphate present should never be less than 15^{cm^3} of the $\frac{n}{10}$ solution. In the case of large dilution the use of freshly boiled water is recommended so as to avoid the reoxidizing effect of the air upon the reduced iron. In the experiments included in the following table, the above precautions were closely adhered to and manifestly satisfactory results were obtained.

TABLE IV.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3.	Excess $Na_2S_2O_3$. cm^3.	Fe_2O_3 found. grms.	Error. grms.
30.	·0125	·0125	200	⅛	23·5	·0125	·0000
31.	·0250	·0250	400	¼	21·98	·0250	·0000
32.	·0250	·0250	400	¼	17·	·0250	·0000
33.	·0250	·0250	400	¼	17·	·0250	·0000
34.	·0500	·0499	400	½	24·	·0498	·0001 —
35.	·0500	·0499	400	½	19·	·0498	·0001 —
36.	·0500	·0499	400	½	15·1	·0497	·0002 —
37.	·0500	·0499	400	½	19·	·0498	·0001 —
38.	·1001	·0999	400	1	23·1	·0993	·0006 —
39.	·1001	·0999	400	1	17·93	·0997	·0002 —
40.	·1001	·0999	400	1	22·92	·0997	·0002 —
41.	·1001	·0999	400	1	18·	·0997	·0002 —
42.	·1001	·0999	400	1	16·	·0996	·0003 —
43.	·1498	·1495	600	1½	23·26	·1493	·0002 —
44.	·1498	·1495	600	1½	16·66	·1493	·0002 —
45.	·1498	·1495	600	1½	26·87	·1475	·0020 —
46.	·1996	·1992	800	2	22·38	·1990	·0002 —
47.	·1996	·1992	800	2	17·29	·1999	·0007 +
48.	·1996	·1992	800	2	22·20	·1991	·0001 —
49.	·4045	·4037	1600	4	16·03	·4042	·0005 +
50.	·4045	·4037	1600	4	16·2	·4023	·0014 —
51.	·4018	·4010	1600	4	16·34	·4007	·0003 —
52.	·5051	·5041	1800	4	15·27	·5026	·0015 —

As seen in the table this process is very accurate, especially in the use of small amounts of ferric oxide. The introduction of cupric sulphate as recommended by Oudemanns, or of sodium salicylate according to Haswell's method, seems to be unnecessary and only complicates the process.

In treating ferric oxide, the following method of procedure is recommended. Dissolve an amount not exceeding 0·2 grm. of the oxide in hydrochloric acid, evaporate to a pasty mass, dilute to about 800^{cm^3} with freshly boiled water, add a drop of potassium sulphocyanide, and into this solution run 50^{cm^3} of approximately $\frac{n}{10}$ sodium thiosulphate; allow the liquid to stand until perfectly colorless and determine the excess of thiosulphate by $\frac{n}{10}$ iodine and starch. For quantities of iron oxide up to 0·2 of a grm. this process is quick and most accurate; when care is taken to preserve the relations of acidity and dilution, twice the amount of ferric oxide mentioned above may be handled.

In conclusion I wish to thank Prof. F. A. Gooch for his kind advice and many suggestions.

ART. V.—*The Mouth of Grand River;* by E. H. MUDGE.

REFERENCE to a map of Michigan will show that the mouth of Grand River, as commonly understood, is at Grand Haven, where the chief river of the State loses itself in the waters of Lake Michigan. But there is another point seventy miles inland which to one familiar with the old river valley, with its varied and interesting history during recent geological times, presents itself to the mind as the mouth of Grand River in a very interesting sense.

The history of this old river valley, in the days when it served as an outlet for the glacial lake Saginaw, has become quite well known to the geological world through the labors of several enthusiastic investigators, notably Mr. Frank B. Taylor, whose final solution of the chief problem here presented was first made public through a paper* read before the Geological Society of America in 1896. To understand thoroughly the matters under discussion in the present paper, a reading of Mr. Taylor's able paper is recommended, especially pages 48 to 54. The point of chief importance to the present discussion is that at one time a great glacial stream, three-fourths of a mile in width as indicated by the old valley, flowed across the peninsula from Lake Saginaw to Lake Chicago. At the point above referred to, in the eastern part of Ionia County (see map accompanying Mr. Taylor's paper), this great river received the waters of another stream, which had its rise far to the south, almost within shouting distance of the Indiana line. This stream was the upper part of what is now known as Grand River. There is no reason to believe that it was ever any larger than at present, and it was therefore but a branch of the great glacial river, with its mouth at the point above indicated.

Long ago the sources of the glacial river failed, and the wide valley with its record-bearing deposits was laid bare to await the time when the inquisitive geologist should investigate its secrets. Among other things thus rendered accessible are the fine river-mouth deposits about this old mouth of Grand River.

The Pewamo outlet (as the glacial river has been named by Mr. Taylor) was relatively a sluggish stream, its fall being something less than one foot per mile, while the fall of the upper Grand is three or four times as great. The surface of the country through which the latter flows is composed chiefly of loose drift materials, well calculated to supply to the stream large quantities of sediment, which, in obedience to a well known law of river action, would be precipitated at the point where the stream joined its waters with a body of still water or with a slower stream. In this case such deposition took place at the old mouth, and in consequence the wide valley here exhibits some interesting features.

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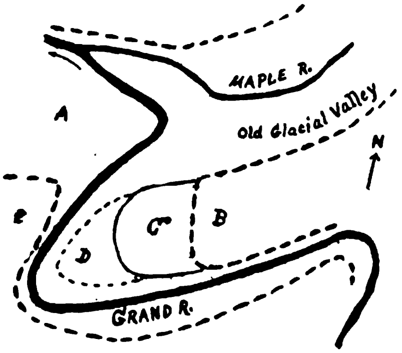
* "Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan," by Frank Bursley Taylor, Bulletin of G. S. A., vol. viii, January, 1897.

The first of these to attract the attention of the observer is the curious meanderings of the two streams before a junction is effected. The Maple River, which occupies the old valley above this place, flows in a channel near the center of the same until a point opposite the old mouth is reached, when it veers over against the north wall of the valley (see map). The Grand, coming in from the south, makes its way through the mass of old sediments (actually flowing "up stream" with reference to the glacial valley, in order to do so), until within a few rods of the Maple, and then turns down the valley and flows nearly parallel with the Maple for some distance before forming a junction, beyond which the united streams keep close to the north side of the valley for four or five miles. It is readily seen that these peculiar conditions are due to the clogging of the valley, in the vicinity indicated by A on the map, by the abundant sediment brought down by the Grand. There is a marked contrast between this area of abundant sediment and that a little farther to the east on the opposite side of the Grand. The latter is subject to overflow during freshet periods, while the former is built up to a considerable height above high water. These conditions continue for about two miles down the valley, along the south side, the filling being so extensive that the steep bluffs are partly obliterated, being replaced by a more gentle declivity. A well-defined terrace, which will be again referred to farther on, also tends to destroy the bluff feature. Immediately above the mouth the bluffs are again steep and prominent.

Some terraces about the old mouth are of considerable significance. When Mr. Taylor examined the valley of the Pewamo outlet in 1896, he called on the writer at Ionia and together we searched in that vicinity for terrace remnants that might indicate the height of the water in the glacial stream, but found nothing of a definite character. I suggested to him that such terraces may have been sheltered and preserved about this old river mouth, but rain and lack of time prevented a visit. I have since had opportunity to study the locality, and am able to report several well-defined and quite extensive terraces.

In the days of the glacial outlet there appears to have been here a small embayment, half a mile or more in extent in either direction. This embayment and the terraces now existing within it are indicated on the accompanying map. The heavy broken line indicates the bluff margin of the main valley and the embayment. From the high ground at B one descends abruptly to the terrace C. This is perhaps the most important of the series. Its elevation has not been measured, but it may be said roughly to occupy a place about midway between the top and the bottom of the main valley. Its surface is smooth and even, with abundant coarse sand and gravel upon it—a sort of gravel loam—together with patches of vegetable mould. South of this terrace, on the opposite side of the Grand, there is a corresponding terrace, sharply defined but only a few rods in width—a mere shelf against the face of the steep bluff. Terrace C inclines gently to the west, the total descent being perhaps 15 or 20 feet. This terrace is so definite a feature of the locality that one can scarcely resist the conclusion that it marks a stage of the ancient river. An eye estimate of its elevation, made from the railway station across the valley at Muir, places it about 20 or 30 feet above the station, which is 656 feet above sea-level. An elevation of from 675 to 685 feet may therefore be taken as a fair estimate.



The nearest point to which Mr. Taylor traced the old beaches of the Saginaw Valley is at Maple Rapids, 25 miles away. At that place he assigns to the Forest beach, the lower of the two, an approximate elevation of 680 feet. The correspondence between this figure and the estimated elevation of terrace C is so close that the conclusion that they are equivalents is quite irresistible.

The descent from C to D is well marked but not steep. The surface is flat and several feet above the annual overflow of the Grand. It apparently corresponds in height with the sediment-filled area at A, and its presence appears to have no special significance. The two terraces described form the site of the village of Lyons.

A third terrace, high above the others, is found across Grand River to the west, covering a considerable area at E. Its limit is marked by a line of low hills, beginning near the big bend of the Grand and extending across northwest to the main valley. It is this terrace that helps to modify the bluff feature in this vicinity, above referred to. It may quite likely be correlated with a high terrace remnant seen at Ionia and with others mentioned by Mr. Taylor, but it is, I think, much better defined and more extensive than any of its probable equivalents hitherto observed. Its position is such that it may be considered tentatively as a portion of the Duplain beach, which Mr. Taylor traced as far as Maple Rapids.

The evidence from this little embayment is on the whole quite in harmony with that from other sources, in its bearing upon the history of the Pewamo outlet.

Lyons, Mich.

ART. VI. — *Electrical Measurements;* by HENRY A. ROWLAND and THOMAS DOBBIN PENNIMAN.*

IN a previous article† mention was made of some work then being carried on at the Johns Hopkins University to test the methods for the measurement and comparison of self-inductance, mutual inductance, and capacity there described.

In the present paper, there will be given an account of the experiments performed with some of the methods described in the previous article, together with a method for the direct measurement of the effect of electric absorption in terms of resistance.

The methods that were tried were 25, 26, 9, 3, 12 and 6.

APPARATUS.

Description of the electrodynamometer, dynamos, coils, condensers, resistances and connections used in the experiments.

Electrodynamometer. — The electrodynamometer was one constructed at the University, having a sensitiveness, with the coils in series, of 1 scale division deflection for ·0007 ampere.

The hanging coil was made up of 240 turns of No. 34 copper wire B and S gauge. The coil was suspended by a bronze wire connected with one terminal of the coil. The other terminal of the coil was a loop of wire hanging from the bottom of the coil and attached to the side of the case; both the suspension and the loop were brought out to binding posts. The resistance of the coil with suspension was 21·7 ohms.

The fixed coils were made up of 300 turns each of No. 30 B and S gauge copper wire. The coils were wound on cup-shaped metal forms and soaked in a preparation of wax. The form was then removed and the coils placed a radius apart as in the arrangement of Helmholtz.

Dynamos.—There were two dynamos used, a Westinghouse alternator, and a small alternating dynamo constructed at the University. The Westinghouse dynamo was one having 10 poles so that each revolution of the armature produced 5 complete periods. The period of this dynamo was determined by taking the time of 1000 revolutions of the armature. This was accomplished by having the armature make an electric connection with a bell every 200 revolutions and taking the time of 5 of these. The taking of the speed during every experiment gave more regular results, as the speed was constantly changing, the dynamo being run by the engine in the University power-house when it was subject to great change of load. This dynamo had a period of about 132 complete periods per second.

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*This Journal, iv, p. 429, December, 1897; Philosophical Magazine, January, 1898.

† Abstract of Thesis for the degree of Ph.D.

For the production of a current of less period than that of the Westinghouse, the small alternator constructed at the University was used. This dynamo was run by a small continuous Sprague motor. The armature of the small alternator consisted of 8 coils, which coils were fastened flat on a german silver plate, the plate revolving between 8 field pieces producing 4 poles. The object of having the coils of the armature on a metal plate was to secure a nearly constant speed. The metal plate produced a load that varied as the velocity and due to induced currents in the plate. The varying load, depending on the velocity of the moving plate, produced a nearly constant speed, which rendered unnecessary the constant taking of the speed. When this dynamo was used, the speed was only determined two or three times during a series of readings or experiments. The average of these determinations was taken as the speed during the whole series of experiments under consideration.

Coils.—The coils whose inductances were determined were all made in the same way, being wound on a metal form and soaked in a preparation of wax. When the wax was hard the metal form was removed. This enabled the coils to be placed close together, as their sides were flat and smooth. The coils all had the same internal and external diameter, but their width varied, that being determined by the number of turns that were desired.

Coils. P_1. External diameter $35{\cdot}46^{cm}$, internal diameter $23{\cdot}8^{cm}$, was made up of about 1200 turns of No. 16 B and S gauge single covered cotton copper wire, roughly wound; the turns were not smooth; self-inductance as finally determined ·566 henry.

P_2. Same dimensions. Turns were put on evenly. The number of turns was 1300 of No. 16 B and S single covered cotton copper wire. Self-inductance ·724 henry.

A. Same internal and external diameters as P, but the width was $4{\cdot}3^{cm}$. Number of turns 3700 No. 20 B and S gauge single covered cotton copper wire. Self-inductance as determined 5·30 henrys.

B_1B_2. This coil was made by winding two wires in parallel and all four of the terminals brought out to binding posts. Thus the coils could be used as two single coils, when the coils will be denoted by the symbols B_1 and B_2 as the case may be, or as a single coil, the coils B_1 and B_2 being joined up in series or in parallel. The dimensions of the coils B_1 B_2 were the same as A. Each of the coils B_1 and B_2 were made up of 1600 turns of No. 22 B and S single covered cotton copper wire. The self-inductance of these coils taken separately when compared with P, which was determined absolutely, was nearly 1 henry. On this account B was taken as being 1 henry, and the other coils were compared with it as a standard.

C. Same dimensions as P_2. Number of turns 1747 of No. 22 B and S single covered cotton copper wire. Self-inductance as determined 1·30 henrys.

Condensers.—2 and 3. Two paraffined paper condensers that had a capacity of 2 and 3 microfarads respectively.

$\frac{1}{8}$d Troy. A $\frac{1}{8}$d microfarad standard mica condenser built by the Troy Electric Co.

$\frac{1}{8}$d Elliott. A $\frac{1}{8}$d microfarad standard mica condenser built by Elliott Bros.

Resistances.—The resistances used in the experiments were of two kinds, those wound with double wire so as to have no self-inductance, as the ordinary resistance box, and those wound on frames or cards which had some small self-inductance, but almost no electrostatic capacity. The resistances which had self-inductance are called open resistances to distinguish them from resistance boxes, and were of different kinds and dimensions.

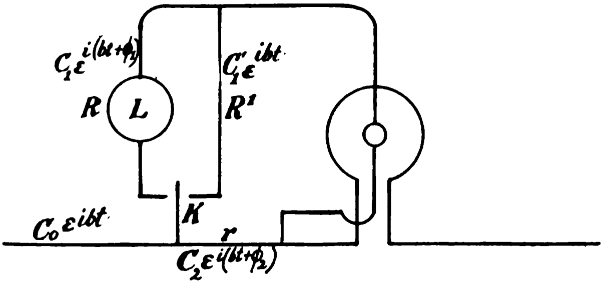
Sources of Error and Experimental Difficulties.

In all work with alternating currents there are two great sources of error that have to be guarded against. These are the errors that may arise from the inductance of one part of the apparatus on another, as, for example, the direct induction of a coil in the circuit on the coils of the electrodynamometer, and the effect of the electrostatic capacity of the leads and connections. In connecting the coils great care had to be taken to avoid the effect of electrostatic action of the leads and connections. For if there was a current of very considerable magnitude, the difference of potential between the terminals of the coil might be great. If the connections under these circumstances were made with double wire, as is customary, a great error was introduced due to the electrostatic capacity of the leads. The error was sometimes as much as 7 per cent (see method 24). This error could be shown to be due to the electrostatic action of the leads by shifting a resistance in circuit with the coil in question from one end of the double wire to the other. The effect of this was to still further increase the difference of potential between the leads, and this increased the error. Experiments of this character showed the necessity of using open leads and open resistances having little or no capacity in all cases in which the coils experimented on and the resistance boxes used in their determination have a current of any considerable magnitude passing through them. In several of the following methods constancy of current was necessary. This was accomplished by various means that will be described in their actual application.

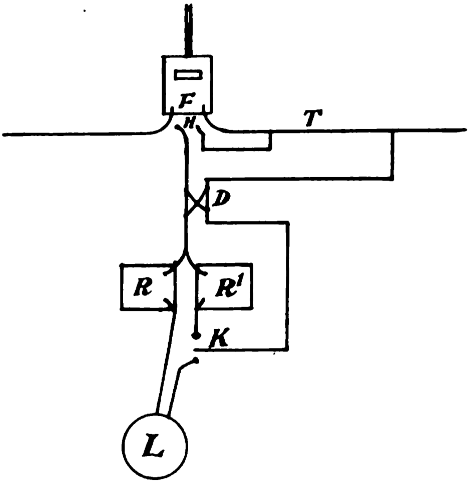
METHODS.

The methods that were tried were 25, 26, 9, 3, 12 and 6 described in this Journal, December, 1897.*

1.


$C_1 \varepsilon^{i(bt+\phi_1)}$
R
L
$C_1' \varepsilon^{ibt}$
R'
$C_0 \varepsilon^{ibt}$
K
r
$C_2 \varepsilon^{i(bt+\phi_2)}$

2.



Method 25.—Method of equal deflections. Absolute method for the determination of self-inductance or capacity in terms of electromagnetic units.

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* Phil. Mag., January, 1898.

In this method the hanging coil is shunted off the fixed coils circuit, and this with a non-inductive resistance in circuit with the hanging coils is made the same as that of a certain inductive resistance in circuit with the hanging coil. The connections are made as in the figs. 1, 2, where $C_0\epsilon^{ibt}$, $C_1\epsilon^{i(bt+\phi_1)}$, $C_2\epsilon^{i(bt+\phi_2)}$ are currents. R, R′, r, resistances. They represent the entire resistance of their respective branches. L represents self-inductance of the coil by which it is placed. The outer circle in fig. 1 represents the fixed coils and the small circle the hanging coil of the electrodynamometer. In fig. 2 the terminals of the fixed and hanging coils are represented by F and H. D is a reversing commutator. K is a key to send the current first through the inductive and then through the non-inductive resistance. $b = 2\pi n$, $n =$ complete alternation per sec. This is the general notation adopted throughout the article.

The quantity to be found is $C_0C_1 \cos \phi_1$, which is proportional to the deflection of the hanging coil in the two positions of K.

In one position

$$C_1\epsilon^{i(bt+\phi_1)}(R+ibL) = C_2\epsilon^{i(bt+\phi_2)}r = (C_0\epsilon^{ibt} - C_1\epsilon^{(ibt+\phi_1)})r$$

Therefore

$$C_0C_1 \cos \phi_1 = C_0 \frac{2r(R+r)}{(R+r)^2+b^2L^2} \, a\, D$$

In the other position of K

$$C_1'\epsilon^{ibt}R' = C'_2\epsilon^{ibt}r = (C_0\epsilon^{ibt} - (C_1'\epsilon^{ibt})\, r$$

Therefore

$$C_0C_1' = C^2_0 \frac{r}{R'+r} \, a\, D'$$

$\phi = 0$, as ϕ is an angle whose tangent is $\frac{bl}{R'}$ and $C = 0$ nearly. In the case of equal deflection $D = D'$ and therefore

$$b^2L^2 = (R'-R)(R+r)$$

If capacity had been used in the place of self-inductance the formula would be

$$\frac{1}{b^2c^2} = (R'-R)(R+r)$$

If self-inductance and capacity were used in series

$$b^2\left(L - \frac{1}{b^2c}\right)^2 = (R'-R)(R+r)$$

The application of this formula to the measurement of self-inductance gave results that agreed to within the accuracy with which the period of the alternations could be determined.

That is, the results agreed to within about 1 per cent. In the determination of L the resistance in circuit R was varied from the least possible resistance as determined by the coils up to 1000 ohms and more, and the self-inductance was determined under these various conditions. These results agreed among themselves, and were apparently independent of the resistance in circuit with it. In the application of this method to the determination of capacity, however, great trouble was encountered, as the capacity apparently varied both with the resistance in circuit with it and with the period. This variation was regular for each period, the value derived depending on the resistance in circuit. This irregularity of derived value of the capacity led to the investigation and development of Maxwell's formula on the effect of absorption, a necessary characteristic of heterogeneous substances.

When the formula was deduced, as may be seen in the article already referred to, the absorption comes in as an added resistance, the resistance being constant for a given period. By an inspection of the results this was found to be the case. The finding of the resistance due to absorption in this method is one of approximation, but the values deduced compare very favorably with those determined by direct measurement, as will be seen later when various results are collected. In the actual experiments the condensers used were two paraffined paper condensers of about 2 and 3 microfarads. The currents used had different periods, as seen in the table following, where $n = 133, 53{\cdot}3, 31{\cdot}9$ and 14.

The process was to place in the condenser circuit a resistance R, and then to move the key K back and forth until R′ was found that gave the same deflection. D, fig. 2, was now reversed and the process repeated. This was repeated with different values of R and n and the apparent capacity. This gave great variation of apparent capacity with different values of R, which should not be the case, and, therefore, gave a means of finding the resistance due to absorption or absorption resistance, as we will designate, by approximation. As the effect of absorption is a resistance it is possible to find what resistance, if added to R, will make all the values of the capacity as determined for the different values of R the same. Therefore it should be the same for any two values of R. Calling the two values of R in the two cases R_1 and R_2 respectively and the two corresponding values of R', R_1', and R_2', and let A be the added resistance due to absorption, the capacity should be the same in the two cases, or

$$\frac{1}{b^2c^2} = [R_1' - (R_1 + A)][R_1 + A + r] = [R_2' - (R_2 + A)][-R_2 + A + r]$$

$$\therefore A = \frac{(R_2' - R_2)(R_2 + r) - (R_1' - R_1)(R_1 + r)}{R_1' - R_2' - 2(R_1 + R_2)}$$

From this A is found for the period used. By doing this for a number of different values of R, the true value of A is approximated. A was thus found for the condensers 2 and 3 microfarads with different values of n. The calculations were again performed adding to the different values of R a constant resistance A. The capacity that was found when A is added to R is called the corrected capacity. In the table below are collected the corrected values of the capacities together with n and the resistance A.

Capacity	4·94	4·96	4·96	4·64	microfarads.
n	131·1	53·3	31·98	14·	complete alternations.
A	5·19	20·5	34·09	139·62	absorption resistance in ohms

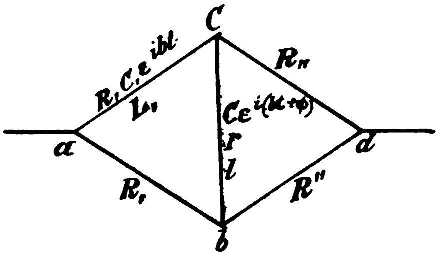
The last value of the capacity seems to be an error, possibly one of calculation. However, the results seem to show a nearly constant capacity, but a resistance increasing rapidly with decrease of period, as Maxwell's formula shows. The constant value of the capacity remains to be explained.

But in the above, determinations of absorption resistance are by approximation. Professor Rowland has, therefore, devised a method by which it can be measured directly. This method, with the results that have been derived by it, will now be given.

Method for the Direct Measurement of Absorption Resistance.

In a Wheatstone bridge (fig. 3) let the resistance of the different arms be denoted by $R_,$, R', $R_{,,}$, R'' and r. Let $R_,$ have in circuit a self-inductance $L_,$ and let r have in circuit with it a self-inductance.

3.



Let $C_,\epsilon^{ibt}$ be the current through $R_,$ and $C\epsilon^{i(bt+\phi)}$ be the current through r when a periodic electromotive force is applied to a and d in the figure.

Let $C_,'$ be the current through $R_,$, and C' be the current through r when there is a constant difference of potential between a and d. The ratio of the current in this case is

$$\frac{c'}{C_{,}'} = \frac{R''R_{,} - R'R_{,,}}{R'(R''+R_{,,}) + r(R'+R'')}$$

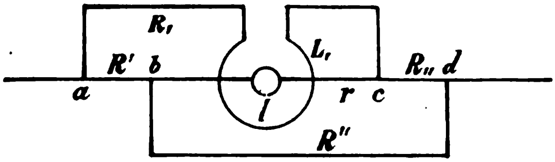
When a periodic electromotive force is applied to *a* and *d*, the ratio of the currents in this case is

$$\frac{c}{C_{,}}\epsilon^{i\phi} = \frac{R''R_{,} - R'R_{,,} + ibR''L_{,}}{R'(R''+R_{,,}) + r(R'+R'') + ibl(R'+R'')}$$

Separating the real and imaginary parts

$$\frac{c}{C_{,}}\cos\phi = \frac{(R''R_{,} - R'R'')[R'(R''+R_{,,}) + r(R'+R_{,,})] + b^2lL_{,}R''(R'+R'')}{[R'(R''+R_{,,}) + r(R'+R'')]^2 + b^2l^2(R'+R'')^2}$$

4.



If now the fixed coils of the electrodynamometer are placed in the $R_{,}$ arm of the bridge, and the hanging coil is placed in cross connection of the bridge, as in fig. 4, the different resistances may be adjusted until there is no deflection, in which case $\phi = 90°$ or $\cos\phi = 0$, therefore

$$(R''R_{,} - R'R_{,,})\,[R'(R''+R_{,,}) + r(R'+R'')] + b^2lL_{,}R''(R'+R'') = 0$$

$$\therefore\ R''R_{,} = R'R_{,,} - b^2lL_{,}\frac{R''(R'+R'')}{R'(R''+R_{,,}) + r(R'+R'')}$$

If in connection with L′ a capacity C is added, the formula becomes, substituting for $L_{,}$, $L_{,} - \frac{1}{b^2c}$

$$R''R_{,} = R'R_{,,} - \left(b^2lL_{,} - \frac{l}{c}\right)\frac{(R''R'+R'')}{R'(R''+R_{,,}) - r(R'+R'')}$$

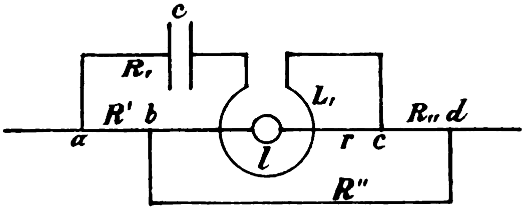
In most cases since l and $L_{,}$ are generally the self-inductances of the instruments the term $b^2\,l\,L_{,}$ can be neglected in comparison with $\frac{l}{c}$ and the equation becomes

$$R''R_{,} = R'R_{,,} + \frac{l}{c}\,\frac{R''(R'+R'')}{R'(R''+R_{,,}) + r(R'+R'')}$$

In this equation $R_{,}$ includes both the ohmic and the absorption resistance. The value of $R_{,}$ is determined in terms of known quantities, that is the resistance and l and C. It was not necessary that l and C should be exactly known as the last term in the equation above plays the part of a correction term, and is in all cases below small and in some cases negligible. The capacities that were used in the experiments were the 2 and 3 microfarads, the ⅛ microfarad Elliott condenser, and the ⅛ microfarad Troy condenser.

Experiments—The process of experimenting was to apply a periodic electromotive force to a and d, and to adjust the different resistances until there was no deflection of the coil in the same way as in the ordinary measurement of resistance on a Wheatstone bridge. The different resistances R', R'', $R_{,,}$ and r being known, the apparent value of the resistance $R_{,}$ was found, and knowing the ohmic resistance of the $R_{,}$ circuit, the absorption resistance appears as the difference.

5



Some interest lies not alone in that the method is applicable, but that it confirmed the supposition that absorption resistance acts as an ordinary ohmic resistance in series in the circuit. This was confirmed by the fact that when condensers were in series and in parallel, their absorption resistances acted under these conditions like ohmic resistances, being increased in the one case and decreased in the other, and in the right ratio. This agreement was not exact, as the absorption resistance was extremely sensitive both to change of period and change of temperature. The great sensitiveness to change of temperature was shown either by letting the current go through the condensers for a little time, or placing the condensers before a hot air flue; in either case after cooling, the absorption resistance returned to its original value. The cooling was very slow, as there was very little radiation from the condensers inclosed in wooden boxes.

The results are now given for the condensers 2 and 3 microfarads. In the calculation of the results the last term of the equation, that is $\frac{l\,R''(R'+R'')}{c\,R'(R''+R_{,,})+r(R'+R'')}$ has been left out, as it was very small when condensers 2 and 3 microfarads were used.

CONDENSERS 2 AND 3 MICROFARADS IN PARALLEL.

$n=134$, $l=\cdot 0007$ $\therefore$ last term negligible.

R''	R_a	r	R'	$R_{,}$	Resis. of R' circuit in ohms.	Resistance due to absorption.
422·6	488·6	5457·3	347·9	39·29	33·77	5.30
1488·6	488·2	“	123·4	40·50	“	6·73
984·1	“	“	82·1	40·72	33·81	6·91
2671·6	“	“	22·5	41·116	“	7·30
423·0	“	“	357·3	41·237	“	7·42
5474·3	“	“	464·5	41·42	“	7·61
6734·	“	“	374·9	41·67	“	7·86
1 ohm in $R''=\frac{3}{4}$ scale division.					“	
7486·	“	“	638·6	41·64	“	7·83
9466·	“	“	81·15	41·85	“	8·04

Condensers 2 and 3 placed before the register and heated for 1 hour:

7489·7	488·27	“	713·8	46·534	34·33	12·20

After standing $1\frac{1}{2}$ hours in air at temperature of 12°·2 C. condenser has been open so that resistances have been cooled:

1240·5	487·8	“	109·	42·86	34·	8·86

After standing some little time:

7482·5	487·8	“	651·6	42·47	34·	8·49

The above table shows conclusively the heating of the condenser by the current, and the dependence of the absorption upon the temperature.

CONDENSERS 2 AND 3 IN PARALLEL. N=57·6.

R''	R_a	R'	r	$R_{,}$	$R_{,}$ in ohms.	A.
348·5	488·6	396·3	11020·7	55·61	33·77	21·84
7488·	“	849·2	“	55·41	“	21·64
“	“	844·1	4026·	55·07	“	21·30
3485·	“	396·1	“	55·58	“	21·81
					Average,	21·63
N=56·6 per second.						
3485·	200·24	976·7	4026·	56·00		22·23

Comparing these values with those found in the use of method 25 the agreement is at once apparent.

N=	134·	131·	57·6	56·6	53·
Method 25		5·19			20·5
Direct measurement.	5·30 cold 7·00 warm		21·63	22·23	

It should be remembered, in comparing the results, that the values obtained by Method 25 would naturally be smaller than those found by direct measurement, as in Method 25 the current going through the condensers was extremely small; there was therefore practically *no* heating.

The experiments that confirm the mathematical theory that the absorption resistance could be treated as ordinary ohmic resistance were performed with the two condensers, ⅛ Troy and ⅛ Elliott microfarad condensers. These are next given.

In these results it was necessary to take into account, in the calculation of the apparent value of $R_{,}$, the last term of the equation, that is

$$\frac{l}{c}\;\frac{R''(R'+R'')}{R'(R''+R_{,,})+r(R'+R'')}$$

⅛ Troy and ⅛ Elliott in series, 1 o'clock.

R''	$R_{,,}$	R'	r	Apparent value of $R_{,}$	Ohmic resistance of $R_{,}$	Absorption resistance A.
4751·8	499·9	404·8	4754·	43·141	34·143	8·998
⅛ Troy, 2 o'clock.						
4750·	497·75	352·4	"	37·288	34·144	3·144
⅛ Elliott, 2.45 o'clock.						
4749·3	497·67	390·3	"	41·260	"	7·116
⅛ Troy and ⅛ Elliott in parallel, 4 o'clock.						
4749·3	497·6	350·23	"	36·94	34·15	2·79
⅛ Troy and ⅛ Elliott in series.						
4748·5	497·55	418.15	"	44·612	34·12	10·492

Calculating what the absorption resistance should be for ⅛ Troy and ⅛ Elliott in series, from the absorption resistances of the two condensers when determined separately, it is equal to 10·26 ohms, which is greater than the first and less than the last value above, showing that the condensers were heating during the experiments. Calculating the absorption resistance of ⅛ Troy and ⅛ Elliott in parallel in the same way, it is equal to 2·209 ohms, which is less than the value afterwards obtained by experiment for the same reason.

The method was shown not to be based on any false supposition, by substituting in place of the condenser a coil of known self-inductance. When this was done the value of R_1 as calculated from the other resistances and the self-inductances should be the same as the actual ohmic resistance of the circuit. This was tried with two coils P_2 and A and the agreement was remarkably close, as seen in the next table.

Coil P used in place of condenser in the $R_{,}$ circuit:

R''	$R_{,,}$	R'	r	Deduced value of $R_{,}$	Actual value of $R_{,}$
474·9	487·8	758·2	5457·	77·86	77·8
Coil A in place of condenser in the $R_{,}$ circuit:					
474·9	487·8	218·3	"	224·12	223·9

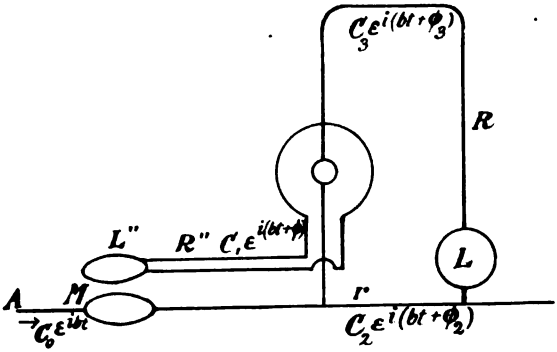
In these experiments great care was taken that the measurements of the resistances were performed immediately after the adjustment. In this way the actual resistances at the time of the experiment were obtained, and so the effect of the heating by the current was somewhat eliminated.

Methods 26, 9 and 3 give good results, but the methods that gave the most satisfaction were Methods 12 and 6, Method 12 being for the comparison of two self-inductances and Method 6 for the comparison of a self-inductance with a capacity. These give some remarkable results, the theory and deductions of the methods being as follows:

Method 12—Zero method for the comparison of two self-inductances.

Let the connections be made as in the figure where the hanging coil and the fixed coils are in two distinct circuits.

6.



$C_3\epsilon^{i(bt+\phi_3)}$
R
L''
R''
$C_1\epsilon^{i(bt+\phi)}$
L
A
M
r
$\rightarrow C_0\epsilon^{ibt}$
$C_2\epsilon^{i(bt+\phi_2)}$

Let $C_0\epsilon^{ibt}$ etc. be the currents, A′ and A″ reversing commutators, R″, R and r the resistance of the different circuits, L″ and L the self-inductances, M the mutual inductance of the coils B_1 and B_2 by which it is placed. When a periodic electromotive force $a\epsilon^{ibt}$ is applied to A, B the quantity to be found is $C_1 C_3 \cos(\varphi_3 - \varphi_1)$ where $\varphi_3 - \varphi_1$ is the difference of phase.

The current in the R″ circuit is then

$$C_1\epsilon^{i(bt+\phi)} = \frac{ibMC_0\epsilon^{ibt}}{R'' + ibL''} \qquad (1)$$

The current in the R circuit is

$$C_3\epsilon^{i(bt+\phi_3)}(R + ibL) = C_2\epsilon^{i(bt+\phi_2)}\,r$$

$$\therefore\ C_3\epsilon^{i(bt+\phi_3)}\frac{R + r + ibL}{r} = C_0\epsilon^{ibt}$$

Substituting the value of $C\epsilon_0^{ibt}$ in equation (1) and simplifying, it becomes

$$C_{,}\epsilon^{i(bt+\phi)} = C_{2}\epsilon^{i(bt+\phi_2)}\frac{-b^2LM+ibM(R+r)}{R''r-ibL''r}$$

Therefore the deflection is proportional to

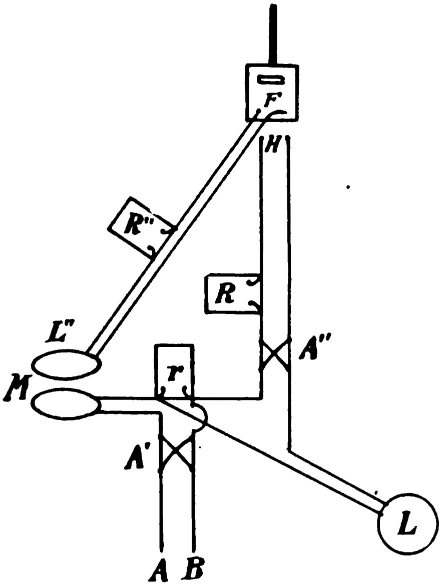
$$D\alpha C_{,}C_{2}\cos(\phi_2\phi_{,}) = C_2^{2}\,\frac{-b_2LMR''r+b^2L''Mr(R+r)}{R''^2r^2+b^2L^2r^2}$$

where D is the deflection. Therefore the condition for zero deflection is

$$-b^2LMR''r-b^2L''Mr(R+r)=0$$

$$\therefore \frac{L}{L''}=\frac{R+r}{R''}$$

7.



The condition therefore of zero deflection is independent of M. But M is one of the factors of the electromotive force in the R″ circuit, and on it therefore depends the sensitiveness, as it determines the current through the R″ circuit. In the first figures of this method the fixed coils are in the R″ circuit, and the hanging coil in the R circuit, but this is not necessary, as the fixed and hanging coils can be reversed. The choice of which of the above arrangements should be used depends on the impedances of the two circuits, as other things being equal the smaller current should go through the hanging coil.

Experiments—The coils used in the experiments were coils P_1, P_2, C, B_1, B_2, and A, which coils are described on page 36. From the dimensions of P_2 and its self-inductance as found by Method 25, B_1 was designed to have a self-inductance of one henry. This will be shown to be nearly the case. For ease of comparison B_1 has been taken in the calculations of the results as being equal to one henry, and the other coils were compared with this coil as a standard.

In these experiments the connections were made as in the figure 47, the coil B_1 that was taken as the standard being placed in circuit with the fixed coils of the electrodynamometer as L'' and the resistance of this circuit was unaltered during the experiments in any particular series. The coils whose self-inductances were to be determined were placed in the hanging coil circuit and the resistance R was changed until there was no deflection. The resistance of the two circuits, R'' and $R+r$ were then measured by a Wheatstone bridge.

The resistance r was in all cases small in order that $C_0\epsilon^{ibt}$ should be large, and therefore by induction $C_1\epsilon^{i(bt+\phi)}$ the current through the fixed coils was made large and the instrument sensitive. The method being very accurate, as will be seen later, great care had to be used to eliminate all sources of error, as for example, electrostatic action. In the first trial of the method small differences were noticed in the ratio of two self-inductances, depending both on the resistances used, and also on the connections of the coils, whether the leads were double, single, long or short. The same variation was noticed when several coils were joined in series and compared with another coil, and when these coils were compared separately and their sum taken.

This irregularity led to an investigation of the effects of various resistances and connections in one of the circuits, the other circuit being unaltered. A little farther on, the variation in the deduced value of the self-inductance of one of the coils, when different resistances and leads were used, will be given, which variation was caused by the electrostatic action of the connections, etc. (Page 37.)

The necessity of eliminating electrostatic action made obligatory the use of open resistances which had small self-inductances. These resistances were of three kinds—resistances in the form of spirals, resistances wound on thin strips of micanite or paper, and those wound on open frames; see page 37.

The self inductance of the first and second classes of resistances was very small, as in one case there were only a few turns, and in the other the cross-section was very small.

The third class were those wound on frames whose self-inductances were calculated. There were several resistances of 2000 ohms each, whose self-inductances were ·0000436 henry, which would hardly affect the phase of the current or the impedence of the circuit.

These coils were subdivided into resistances of various amounts. Another frame resistance used was of 7463 ohms divided into parts of about 250 ohms each. The self-inductance of the entire 7463 ohms was ·000105 henry.

As the open resistances were not divided into small amounts it was necessary to use resistance boxes for adjustment; as few ohms as possible were used in each case.

From the fact that the coils of the electrodynamometer had self-inductance a correction was introduced in order that the ratio of the resistances should give the ratio of the self-inductances of the coils direct.

The value of this correction in ohms was calculated as follows:

Calculation of connection due to fixed and hanging coils.

Self-inductance of fixed coils $= f =$ ·0164 henry
" " " hanging coil $= h =$ ·0007 "

Correction due to fixed coils. From an inspection of the tables it is seen that

$$\frac{L}{B_1+f} = \frac{R+r}{R''}, \text{ or } \frac{L}{1\cdot0164} = \frac{R+r}{902}$$

where L is the self-inductance of some coil and $R+r$ is the corresponding resistance. B_1 is taken as equal to 1 henry

$$\therefore \frac{L}{R+r} = \frac{1\cdot0164}{902}$$

But the comparison of L with $B_1 = 1$ is wanted, therefore both numerator and denominator of $\frac{1\cdot0164}{902}$ are divided by 1·0164 or

$$\therefore \frac{L}{R+r} = \frac{1 = B_1}{887\cdot45}$$

$$\therefore \frac{L}{B} = \frac{R+r}{887\cdot45}$$

That is, the self-inductance ·0164 henry of the fixed coils produced a correction of $887\cdot45 - 902 = -14\cdot55$ ohms, which must be applied to the R″ circuit if the self-inductance of that circuit is to be considered as 1 henry.

Correction due to hanging coil. The self-inductance =·0164 henry of the fixed coils gives a correction of −14·55 ohms, therefore the self-inductance ·0007 henry of the hanging coil gives a correction of −·62 ohms to the R+*r* circuit. Applying these corrections, the results obtained for the several coils under various conditions are given below. The results are given in the following order.

First. The values are calculated using double leads in the circuits but open resistances as far as possible.

Second. The variation of the apparent value of the self-inductance of one of the coils with different positions of the coil, resistances, and different kinds of leads.

Third. Short leads separated about 6 inches and crossed, used with all the coils except B_1.

Fourth. Open leads and open resistances in the determinations. In the table R″ was open resistance plus the resistance of coil B_1 and fixed coils of instrument. R+*r* was made up of the small coil and open resistance plus the amount in the Queen ordinary resistance box.

After all the inductive effect of the leads was removed and the ordinary resistance box used as little as possible, there was a different value obtained for the ratio of the self-inductances dependent on the position of the reversing commutator A′. With all the coils used the greater value occurred with the same position of A′. This was due to the electrostatic action between the coils B_1 and B_2, for if the terminals of the coil B_2 and the commutator A′ were reversed at the same time, there was no change in the value of the ratio of the inductances. This showed that it was dependent on the coil itself and not on the leads and it could therefore not be eliminated.

It is to be noticed that the values obtained for the lower number of alternations are always greater than those found with the higher number of alternations. This was caused by the electrostatic action of the turns of the coil on each other. In the case of the coil P_2 this effect would be caused by supposing a capacity of ·0007 microfarads shunted across the terminals.

The results are now given comparing the different coils with B_1 as a standard and equal to 1 henry.

DOUBLE LEADS OF BELL WIRE AND OPEN RESISTANCES.

$r = 106$ ohms, $n = 45$ complete periods per second.

Coils.	R″.	Correc.		Queen.	R+*r*.	Correc.	Average.	Com. A′.	Ratio.
P_1+P_2 +C	901·6	−14·55	887·05	292	2300·2	—·62	2304·9	1	2·5983
"	"	"	"	310	2311·0	"		2	
C	"	"	"	19	1158 3	"	1169·0	1	1·3099
"	"	"	"	22	1161·2	"		2	
C+P_1	"	"	"	103	1659·	"	1661·2	1	1·8727
"	"	"	"	109	1664·8	"		2	

Coils.	R′.	Correc.		Queen.	R + *r*.	Cor-rec.	Aver-age.	Com. A′.	Ratio.
C + P_2	901·6	—14·55	887·05	92	1800·2	—·62	1802·6	1	2·0288
"	"	"	"	99	1806·5	"		2	
A	901·7	"	887·15	149	4776·5	"	4786·5	1	5·3956
"	"	"	"	196	4818·0	"		2	

Current increased about 2½ times.

A	"	"	"	141	4787·0	"	4781·3	1	5·3898
"	"	"	"	184	4807·	"		2	
A + C	901·6	"	887·05	211	5936·	"	5958·3	1	6·7170
"	"	"	"	264	5982·	"		2	
A + C × P_2	"	"	"	51	6575·5	"	6602·5	1	7·4430
"	"	"	"	104	6631·0	"		2	
A	902·	"	887·45	158	4778·9	"	4795·25	1	5·4036
"	"	"	"	192	4813·	"		2	
P_1 + P_2	"	"	"	183	1146·5	"	1146·7	1	1·9922
"	"	"	"	186	1148·5	"		2	
P_2	"	"	"	7	643·15	"	642·67	1	·7242
	"	"	"	8	643·6	"		2	
P_1	"	"	"	91	502·5	"	502·16	1	·5658
	"	"	"		503·1	"		2	

DOUBLE LEADS. n = about 133 complete alternations per sec.

Coils.	R′.	Correc.		Queen.	R + *r*.	Cor-rec.	Aver-age.	Com. A′.	Ratio.
P_1	901·9	—14·55	887·35	90 + *s*	500·4	+ ·62	499·69	1	·5631
"	"	"	"	"	500·23	"		2	
P_2	"	"	"	3	639·35	"	638·85	1	·7198
"	"	"	"	4	639·6	"		2	
A	901·87	"	887·32	?	4742·2	"	4750·48	1	5·3537
"	"	"	"	133	4760 0	"		2	
C	901·9	"	887·35	44	1151·4	"	1150·94	1	1·2970
"	"	"	"	44	1151·4	"		2	

In the above determinations the coils were arranged in the way as indicated in the figure having leads of double bell wire.

A SERIES OF DETERMINATIONS OF A UNDER VARIOUS CONDITIONS.

Open resistance R on table (original position).

Coils.	R′.	Correc.		Queen.	R + *r*.	Cor-rec.	Aver-age.	Com. A′.	Ratio.
A	902·0	—14·55	887·45	149 + *s*	4776·5	—·62	4786·58	1	5·3936
"	"	"	"	196 + *s*	4818·	"		2	
"	901·95	"	887·4	?	4783·5	"	4795·38	1	5·403
"	"	"	887·4	190 + *s*	4808·5	"		2	

Open resistance R moved up to coil A (b_1).

"	"	"	"	?	?	"			
"	"	"	"	?	4518·	"	4517·38	2	5·0905

Open resistance R moved to the other side of A (b_2).

"	"	"	"	144 + *s*	4518·	"	4518·88	1	5.0922
"	"	"	"	147 + *s*	4521·	"		2	

Coil A placed in P_1 position and open resistance R restored to its position, and 159′ of double wire added to the circuit.

Coils.	R″.	Correc.		Queen.	R+r.	Cor-rec.	Aver-age.	Com. A′.	Ratio.
A	901·95	—14·55	887·4	547·+4129		—·62			
					547	“		1	
					4676		4693·38	2	5·2888
“	“	“	“	583+4129					
					583				
					4712				

Coil A at end of double wire 69′+159′=228′ long.

“	“	“	“	607+4129					
“	“	“	“		607				
					4736				
				634+4129					
					634				
					4763				

New leads placed in B_1 circuit, the wires were about 6″ from each other.

“	902·6	“	888·05	569+4129					
“	“	“	“		569				
					4698				
				594+4129			4709·88	1	5·3038
					594			2	
					4723				

Open resistance placed next Coil A.

“	“	“	“	663+4129			4791·3	1	5·3956
					663		4292·	2	
“	“	“	“		4292		·7		
							0·6		

In the following all connections were made with open leads, and open resistances were used.

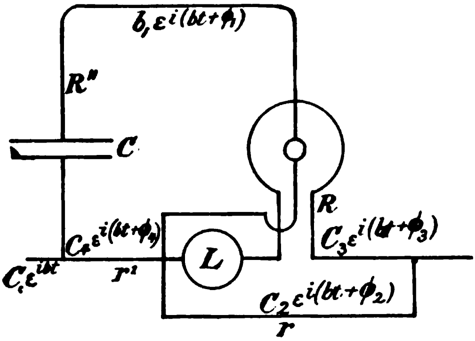
Pe-riod.	Coils.	R″.	Correc.		Queen.	R+r.	Cor-rec.	Aver-age.	Com. A′.	Ra-tio.
40	P_1	902·	—14·55	887·45	90+s	503·07	—·62	502·71	1	·5664
“	“	“	“	“	90+s	503·6	“		2	
133	“	“	“	“	88+s	522·53	“		1	
“	“	“	“	“	88+s	502·15	“	501·72	2	·5653
40	P_2	902·55	“	888·	17+s	644.3	“		1	
“	“	“	“	“	18+s	644·76	“	643·91	2	·7251
133	“	“	“	“	17+s	643·05	“		1	
“	“	“	“	“	17+s	643·1	“	642·45	2	·7234
40	C	902·4	“	887·85	28+s	1159·6	“		1	
“	“	“	“	“	28+s	1159·1	“	1158·73	2	1·3050
133	“	“	“	“	24+s	1157·0	“		1	
“	“	“	“	“	26+s	1158·8	“	1157·28	2	1·3034
40	$C+P_1$	902·	“	887·45	105+s	1658·8	“		1	
“	“	902·	“	“	110+s	1664·1	“	1660·77	2	1·8713
133	“	“	“	“	101+s	1656·7	“		1	
“	“	“	“	“	106+s	1660·3	“	1657·96	2	1·8682
40	$C+P_2$	902·5	“	887·95	10+s	1803·0	“		1	
“	“	“	“	“	12+s	1805·0	“	1803·3	2	2·0261
133	“	“	“	“	8+s	1800·5	“		1	
“	“	“	“	“	8+s	1800·2	“	1799·65	2	2·0221

Period.	Coils.	R″.	Correc.		Queen.	R + *r*.	Correc.	Average.	Com. A′.	Ratio.
40	P_1+P_2+C	902·4	—14·55	887·85	$60+s$	2306·3	—·62	2307·98	1	2·5995
“	“	“	“	“	?	2310·9	“		2	
133	“	“	“	“	$56+s$	2304·1	“	2304·13	1	2·5951
“	“	“	“	“	$57+s$	2305·4	“		2	
40	A	902·43	“	887·88	$85+s$	4703·	“		1	
“	“	“	“	“	$106+s$	4724·2	“	4712·98	2	5·3080
133	“	902·4	“	887·85	$82+s$	4704·2	“		1	
“	“	“	“	“	$85+s$	4707·0	“	4704·98	2	5·2991
40	$A+C-2M$	902·35	“	887·8	$1146+s$	9149·5	“		1	
“	“	“	“	“	$1227+s$	9233·5	“	9190·88	2	10-3515
133	“	902·4	“	887·85	$1170+s$	9171·7	“		1	
“	“	“	“	“	$1194+s$	9191·7	“	9181·08	2	10·3395
40	$A+C+2M$	902·35	“	887·8	$111+s$	2550·9	“		1	
“	“	“	“	“	$146+s$	2556·4	“	2553·03	2	2·8716
133	“	“	“	“	$38+s$	2548·7	“		1	
“	“	“	“	“	$38+s$	2548·7	“	2548·08	2	2·8701
40	$A+C$	902·6	“	888·05	123	5852·	“		1	
“	“	“	“	“	169	5898·	“	5880·13	2	6·6225
133	“	“	“	“	134	5863·5	“		1	
“	“	“	“	“	140	5869·	“	5865·63	2	6·6054

The above results show to what accuracy self-inductances of different values can be compared to each other, or to one of the self-inductances taken as a standard. The reason that the agreement between the different determinations is not greater than it is, even though the electrodynamometer was sensitive to a change of 1 part in 10000 in $R+r$, is that there was always some little heating of the resistances, and although they were measured in each determination on a Wheatstone bridge, still it was impossible to determine the exact resistance at the time that the experiment was made. This slight effect of the heating of the resistances would not enter in the comparison of two nearly equal self-inductances, that is the comparison of a coil with a standard. The accuracy of this comparison can be made to depend on the accuracy with which $R+r$ can be determined for zero deflection, and this can be done to about 1 part in 10000. To do this, first the standard coil and the coil to be compared are substituted in turn in place of L in figure; they are thus compared separately to a third coil. But as the standard and the coil to be compared are nearly equal in self-inductance, the difference or self-inductance can be determined by the amount necessary to change $R+r$, and this change will be nearly independent of the slight heating of the resistances. To make a coil of the same self-inductance as the standard, the standard is placed in the $R+r$ circuit and the value of $R+r$ is found that produces no deflection. The coil to be compared is then substituted in place of the standard keeping $R+r$ fixed, and the self-inductance of this coil is changed until there is no deflection, as in the case of the standard. The accuracy with which this can be done depends on the accuracy with which $R+r$ can be set or 1 part in 10000. This method therefore gives a means of comparing and constructing coils to agree in self-inductance to within 1 part in 10000 with a standard.

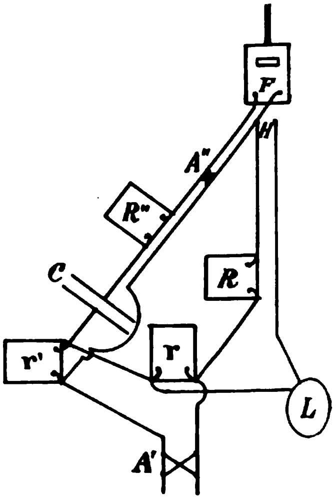
Method 6. Zero Method for the comparison of Self-inductance with capacity.

8.



$b_1\varepsilon^{i(bt+\phi_1)}$
R''
C
$C_4\varepsilon^{i(bt+\phi_4)}$
$C_0\varepsilon^{ibt}$
r'
L
R
$C_3\varepsilon^{i(bt+\phi_3)}$
$C_2\varepsilon^{i(bt+\phi_2)}$
r

9.



This method resembles Method 12 and the connections are made as in the figures when both the hanging coil and fixed coils of the electrodynamometer are shunted off the main circuit.

Let the currents be denoted by $C_0\varepsilon^{ibt}$, $C_1\varepsilon^{i(bt+\phi_1)}$, $C_2\varepsilon^{i(bt+\phi_2)}$, $C_3\varepsilon^{i(bt+\phi_3)}$, and $C_4\varepsilon^{(ibt+\phi_4)}$. The resistance by R'', r', R and r. The capacity by C. The self-inductance by L. A' and A'' are reversing commutators and F the terminals of the fixed coils and H the terminals of the hanging coil of the electrodynamometer.

If now a periodic electromotive force is applied to the terminals A and B the equations connecting the different currents are as below, from which equations the quantity $C_1C_2\cos(\varphi_1-\varphi_2)$ is to be found, which is proportional to the deflection. From the figure

$$C_4\epsilon^{i(bt+\phi_4)}\, r' = C_1\epsilon^{i(bt+\phi_1)}\left(R' + \frac{1}{ibc}\right)$$

$$C_4\epsilon^{i(bt-\phi_4)} = C_0\epsilon^{ibt} - C_1\epsilon^{i(bt+\phi_1)}$$

$$\therefore\ C_0\epsilon^{ibt} = C_1\epsilon^{i(bt+\phi_1)}\, \frac{R''+r' \frac{1}{ibc}}{r'}$$

In the same way it is found that

$$C_0\epsilon^{ibt} = C_2\epsilon^{i(bt-\phi_2)}\, \frac{R+r+ibL}{r}$$

$$\therefore\ C_1C_2\epsilon^{i(\phi_1-\phi_2)} = C_2^2\, \frac{(R+r)r'+ibLr'}{R''+r')r+\frac{r}{ibc}}$$

Therefore the real part is

$$C_1C_2\cos(\phi_1-\phi_2) = C_2^2\, \frac{(R+r)\,(R''+r')rr' - \frac{L}{c}\, rr'}{(R''+r')^2r^2+\frac{r^2}{b^2c^2}}\quad a\,D$$

where D is the deflection. When D is equal to zero

$$(R+r)\,(R''+r') - \frac{L}{c} = 0$$

or

$$\frac{L}{c} = (R''+r')\,(R+r)$$

In the experiments by this method the $\frac{1}{8}$ microfarad Elliott condenser was used, and it was compared with the different coils P_1, P_2, A, and C. The connections were made with open leads and open resistances were used as far as possible, but it was necessary to use resistance boxes for the last adjustments. The connections having been made as in figure, the process of experimenting was to keep r and r' constant and to adjust R″ and R until there was no deflection of the hanging coil. The resistance of the circuits $R''+r'$ and $R+r$ were then measured on a Wheatstone bridge. The commutator A′ was reversed and the process was repeated. The condenser had absorption (see p. 45) which caused the resistance $R''+r'$ to be increased by 7·11 ohms. When the capacity is calculated, taking into account the absorption, it is called the corrected capacity, as in the other tables of the paper.

COLLECTED RESULTS.

Goils.	$n=40$. Results found by direct measurement.	Results found by taking sum diff., etc., of separate meas.	Results found by direct meas. of coils and combination of coils.	$n=133$. Results found by taking sum and diff. of separate measurements.	
P_1	·5664	·5663	·5653	·5648	$(C+P_1)-C=P_1$
"		·5734		·5730	$(C+P_1+P_2)-(C+P_2)=P_1$
P_2	·7251	·7211	·7233	·7187	$(C+P_2)-C=P_2$
"		·7282		·7269	$(C+P_1+P_2)-(C+P_1)=P_2$
C	1·3050	1·3049	1·3034	1·3029	$(C+P_1)-P_1=C$
"		1·3010		1·2990	$(C+P_2)-P_2=C$
"		1·30[illegible]0		1·3065	$(C+P_1+P_2)-P_1-{}_2=C$
A	5·3080	5·3175	5·2991	5·3022	$(A+C)-C=A$
P_1+P_2		1·2945		1·2917	$(C+P_1+P_2)-C=P_1+P_2$
"		1·2915		1·2888	P_1+P_2
$C+P_1$	1·8713	1·8714	1·8683	1·8677	$C+P_1$
"		1·8744		1·8718	$(C+P_1+P_2)-P_2=C+P_1$
$C+P_2$	2·0261	2·0331	2·0221	2·0298	$(C+P_1+P_2)-P_1=C+P_2$
$C+P_1+P_2$	2·5995	2·5965	2·5951	2·5920	P_1+P_2+C
$A+C$	6·6225	6·6130	6·6054	6·6025	$A+C=A+C$

In Method 12 connections due to the hanging coil and fixed coils were calculated so that the ratio of the resistances would give the ratio of the self-inductances direct. In this method (6) since the capacity was in circuit with the hanging coil, the self-inductance was so small that it was neglected. The self-inductance of the coils P, etc., which were joined in circuit with the fixed coils, were increased by the self-inductance of the fixed coils, that is by ·0164 henry.

The table below give the various results.

N.	Coil.	$R''+r$.	Queen in current with $R''+r$.	$R+r$.	Product.	Position of A′.	L.	C.	Cor. C.
							·7251		
40	P	2008·	205·	1095 7	2198522·	1	·0164	·3373	
"	"	2005·	200·	"		2	·7415		
133	"	2024·5	221·	"	2218792·	1	·7233		
"	"	2025·5	222·	"		2	·0164	·3330	·3323
							·7397		
40	A	12741·5	30·	1241·85	15922394·	1	5·3080		
"	"	"	30·	"		2	·0164	·3344	
							5·3244		
133	"	12720·	236·	"	15775610·	1	5·2991		
"	"	12716·	220·	"		2	·0164	·3368	·3363
							5·3155		
40	C	3430·8	98·	1140·8	3911004·	1	1·3050		
"	"	3425·8	93·	"		2	·0164	·3379	
							1·3214		

			Queen in current with			Position of			Cor.
N.	Coil.	$R'' + r$.	$R'' + r$.	$R + r$.	Product.	A′.	L.	C.	C.
133	C	3448·8	$106 + s$	1140·8	3933354·	1	1·3034		
"	"	3447·0	$105 + s$	"		2	·0164	·3355	·3346
							1 3198		
40	P	1578·5	$57 + s$	1088·9	1718719·7	1	·5653		
"	"	1578·4	$58 + s$	"		2	·0164	·3384	
							·5817		

This method can be used with great accuracy for the comparison of the capacity of a condenser with a standard condenser. In the comparison, first one condenser and then the other would be placed in the $R + r$ circuit. If the two condensers are of nearly the same capacity, the degree of accuracy of the comparison depends upon the accuracy with which $R'' + r'$ can be set. The degree of accuracy of setting $R'' + r'$ varies with the value of the self-inductance with which the condensers are compared. In the experiments just given, using the different coils, the degree of accuracy with which two $\frac{1}{3}$ microfarad condensers could have been compared would vary from 1 part in 2000 to one part in 14000. The two condensers are supposed to be without absorption, as its presence would cause trouble unless the absorption resistances were known.

Résumé.—Summing up the results deduced in this paper, it is seen that the methods for the absolute determination of self-inductance and capacity do not give as concordant results as could be wished. The irregularity of results was caused, in the most part, both in the determination of self-inductance and capacity by the variation of the periods of the currents used in the experiments. As the period enters directly into the determination of self-inductance and capacity, all variations of the period will appear in the results. The determination of capacity is complicated by the presence of electric absorption (pp. 44 and 45). The effect of electric absorption is shown to be that of an added resistance in series with the condenser, called absorption resistance. A direct method is given by which absorption resistance can be measured (p. 41), and experiments are given which show that when condensers possessing absorption are in series or in parallel, their absorption resistances act under these conditions as ohmic resistances in series with the separate condensers (p. 45). Absorption resistance is also found to be extremely sensitive to temperature.

The methods for the comparison of two self-inductances or a self-inductance and a capacity are independent of the period, and when the self-inductances are of different magnitudes the comparison can be made with an accuracy of 1 part in 10000. These methods, therefore, give a means of comparison of a self-inductance with a standard self-inductance, or a capacity with a standard capacity to an accuracy of 1 part in 10000, or they allow the establishment of standards.

ART. VII.—*Reflection of Hertzian Waves at the Ends of Parallel Wires;* by LEE DEFOREST.

SINCE the famous experiments of Hertz on electric waves in wires, investigators in this field have found most useful the arrangement known as the Lecher system, or adaptations of this. In its original form this consists essentially of two condensers, each of two metal plates, hung parallel. One pair of these is connected to the secondary terminals of an induction coil, with a spark gap in the circuit. From the other pair of plates lead off two long parallel wires.

By the action of the coil the primary plates are charged with equal and opposite quantities of electricity, which discharge across the gap, when the tension has been raised sufficiently high. Rapid oscillations of a period depending on the capacity of the entire system are thus set up, which induce corresponding impulses in the secondary plates. Electric waves surge over the two wires, to be reflected at their ends with a change in intensity and phase depending on the nature of the terminal arrangement.

Thus standing waves are set up in the wires, which are the better defined, the more nearly the length of the wires approaches an integral number of half wave-lengths.

The ease with which these standing waves can here be measured, and the symmetry and simplicity of the whole arrangement, make this system of the greatest usefulness in all researches where the phenomena of waves in wires are to be studied.

At the nodes of these standing waves, a conducting body, as a wire bridge, may be placed across both wires without interfering with the action beyond.

At an other point, however, such a bridge harms the effect, producing extinction of the glow in a vacuum tube placed across the two wires at their ends.

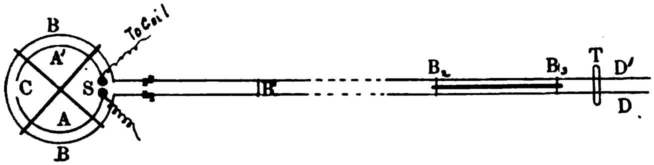
By such means Lecher was enabled to measure readily half wave-lengths, between successive bridges; and inasmuch as theory has shown the velocity of propagation in such a system to be that of light, he could compute the period of the vibration.

With such an apparatus, or with the improved form introduced by Blondlot, an enormous amount of work in determining dielectric constants, indices of reflection, electric dispersion, etc., in fluids, has been accomplished, notably by German physicists. Quantitative experiments have been made with bolometer, electrometer, or thermo-electric means, and thus the attenuation and curves of the standing waves determined.

It was observed that reflection with change of phase occurred at any bridge, bend, or sudden change in the nature of the parallel wires. The mathematical theory for such phenomena has been considerably developed, notably by Drude.*

Theory shows that the waves are reflected at the open ends of the parallel wires without change of sign of electrification. The first node, therefore, would be expected at one quarter of the wave-length from the ends. If capacity of any sort is attached to the ends, however, a change of phase would occur by the reflection and this node be found nearer the ends, by an amount depending on this capacity. Even for bare ends, where no capacity has been assumed, it was early noticed that a change of phase did occur; that the distance to the first node was unexpectedly small.

1.



To investigate this part of the subject was the aim of the experiments described in this paper.

The form of exciter adopted was a compromise between the Lecher and the Blondlot forms. In the latter two pieces of wire, bent semi-circularly, take the place of the primary condenser plates of the Lecher system. To one end of each wire is fastened a small polished zinc ball, forming the spark gap. To the other ends are often attached a pair of metal plates, placed oppositely, to add capacity to the whole.

Outside of the approximate circle thus formed is bent a single wire for the secondary. Its two ends are brought near together, and from these lead out the long parallel wires.

This Blondlot system has a greater damping than the Lecher. Its individual period is less marked, and the frequencies of the waves found upon the parallel wires are almost altogether dependent upon the vibrating systems there formed by bridges arbitrarily located. A great advantage resulting is that a large range of wave-lengths may thus be had from one oscillator.

In the exciter used throughout, instead of wires, two narrow zinc plates, A A′, each 15^{cm} long, $1{\cdot}5^{cm}$ wide in the middle, and *elliptical* in shape, formed the primary. These were bent as shown in Fig. 1, and each carried a zinc ball, 8^{mm} in diameter, centered at a focus of the ellipse together with the leading-in wires. Thus reflections from every part of the edges of the plates were concentrated simultaneously at the gap.

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* Wied. Ann., lii, p. 499; liii, p. 751.

The spark gap between these two balls varied from 1^{mm} to 2^{mm}. About this primary oscillator a similar zinc strip 32^{cm} long was bent to form the secondary. The whole was immersed in a glass vessel containing kerosene oil. But $0{\cdot}5^{cm}$ separated the primary from secondary, and without the oil violent spark discharges passed between all parts of the system. The petroleum was decomposed by the electrical action, carbon being deposited upon the zincs. This oil was renewed from time to time.

This particular arrangement combines advantages of both the Lecher and Blondlot exciters. By the use of plates all the elements of the primary and secondary may be brought closer, the loss of energy found in the Lecher exciter obviated; and the uninterrupted form of the secondary connects the two parallel wires as in the Blondlot, allowing perfect reflection or interchanging of the back-coming waves from DD′. Moreover, the damping of this oscillator was such that its individual period had little effect upon the resonator system of the wires. I could by judicious bridging get almost any wave-length from 50^{cm} to 3 meters. The case was analogous to that of any acoustic vibrating system when struck by a body of any period whatsoever—the primary oscillation caused by the spark discharge serving merely to excite surgings in D B D′, the period of which is determined by the location of the first bridge on DD′.

When the length of the wires DD′ is properly proportioned to the period of the exciter, we have of course the strongest possible action. With a first bridge at 36^{cm} from S, and succeeding ones 43–44^{cm} apart, the vacuum tube, laid across the ends of the wires to serve as a detector, was found to glow with eight bridges on the wires.

For any other wave-length so great a number of bridges quite extinguished the effect of the primary vibrations. I regarded then 86–88^{cm} as the primary wave-length; the natural period, calculated,* is 60^{cm} in oil, giving $86{\cdot}4^{cm}$ in air.

A certain dim glow persisted in the tube, no matter how many bridges were on the wires or where placed. This was found due to the oscillations of the coil, of enormous wave-length, and relatively gradual, unreflected by any form of bridge used, whereas the shorter ones due to the sudden oscillations across S are cut off very sharply. With practice there was no difficulty in distinguishing the different characters of the glow produced by these Hertzian oscillations.

To allow of work in daylight this vacuum tube was completely enclosed in a light-tight box, and viewed through a slot and eye-shade. Then by means of an endless cord passed through two pulleys and running below the wires, the observer stationed at the tube could slide a bridge, attached to the cord by wooden clamps, along the wires.

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* By Drude's method, Wied. Ann., lv, p. 634.

When a node was located by this means, the place was marked, a new bridge hung there, and the sliding bridge then moved farther along the wires. On each bridge was hung a wooden block to hold it fixed in place and in good contact. To facilitate measurements a long scale-piece, graduated in half-centimeters, was below the wires, and the intervals between bridges read therefrom by means of a sliding index arm.

For the purposes intended the vacuum tube was the best indicator known, though but roughly quantitative. To reduce the deforming effect on the standing waves from its capacity to a minimum, no electrode nor tinfoil was used, the bare tube being laid across the parallel wires. Even then it possessed a capacity, as found by a long series of measurements, equivalent to a length of 4^{cm} of the line. This was independent of the wave-lengths used, and was thereafter allowed for in all measurements of wave-lengths where the tube was present.

Relation between Change of Phase in Reflection from Open Ends, and the Frequency.

When an electric wave passes along a conductor we have at any point this relation between the E. M. F. and current:

$$-\frac{d\phi}{dx} - L\frac{dC}{dt} = RC$$

where ϕ = Electro-static potential
C = Current
R = Resistance of the circuit per cm.
L = Self-induction " " "
Let S = Elect. static capacity "
Q = Quantity of electricity per unit length.

Then $C = Q\frac{dx}{dt} = Qv$ where v = the velocity of propagation.

$$\therefore C = S\phi v$$

$$\therefore \frac{d\phi}{dx} + LSv\frac{d\phi}{dt} + VRS\phi = 0$$

When and where $\phi = 0$ we have*

$$\frac{\delta\phi}{\delta x} + LS\frac{\delta\phi}{\delta t} = 0 \qquad (1)$$

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* Barton, Proc. Royal Soc., vol. liv, p. 87.

$$\text{or} \quad \frac{\delta\phi}{\delta t}\,\frac{\delta t}{\delta x} + \text{VLS}\,\frac{\delta\phi}{\delta t} = 0$$

$$\therefore \frac{\delta\phi}{\delta t}\left[v\text{LS} - \frac{1}{v}\right] = 0$$

whence $v = \frac{1}{\sqrt{\text{LS}}}$ or $\text{L}v = \frac{1}{\text{S}v}$, the well-known Thomson formula for the velocity of the propagation of the wave.

Now the capacity per unit length of the normal part of the Lecher parallel wires is given* very closely by the form

$$\text{S} = \frac{1}{4\,\text{Log nat}\,\frac{d}{r}}$$

in electro-static units, where r = radius of the wires, d their distance apart.

In the wires used $r = \cdot 37^{\text{mm}}$; $d = 1\cdot 7^{\text{cm}}$. Also $\text{L} = 4\,\text{Log nat}\,\frac{d}{r}$ in electro-magnetic units. Thus the period of Lecher's system, as well as for circular or rectangular resonators, is independent of r or d. And if the resistance is negligible compared to $2v\text{L}$ (which is the case for wires greater than $0\cdot 5^{\text{mm}}$ diameter or thereabouts, and less than 100^{m} long), the velocity of propagation thereon is that of light. Especially at the point of reflection the resistance R may be neglected. Equation (1) becomes

$$v\frac{\delta\phi}{d\gamma} + \frac{\delta\phi}{dt} \qquad \text{and its solution:}$$

$$\phi = f.\,(nt - \beta_0 x) + f_2\,(nt + \beta_0 x)$$

where $\frac{n}{\beta_0} = v = \frac{1}{\sqrt{\text{LS}}}$ and $f_1\,;f_2$ denote any functions (in our case sine functions) with coefficients for the various amplitudes, and a third term in the parentheses to allow for change of phase. So for the original and reflected waves, where $x = 0$ write:

$$\text{V}_1 = \phi \sin\left(nt - \frac{\delta_1}{2}\right) \qquad (2)$$

$$\text{V}_2 = \phi' \sin\left(nt + \frac{\delta_1}{2}\right)$$

where δ_1 is the angle of change of phase in reflection.

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* e. g. Lord Rayleigh, Phil. Mag., August, 1897.

But we must consider the case of a condenser, of capacity S_1 between the ends of the two parallel wires. Then if V denote the resultant potential-difference in the wires at the ends from incident and reflected waves, and C the resultant current, we have the condenser equation

$$\frac{\delta V}{dt} = \frac{C}{S_1} \quad \text{if there is no transmitted}$$

wave; and b, the coefficient of reflection, equals 1.

But in the case of open ends we must suppose a part of the energy radiated off, either in expanding, approximately spherical, waves, or for a distance as a beam, more or less plane polarized. The amount lost will be greater the less the capacity of the end condenser.

But for our purpose it is unnecessary to determine the exact course or nature of the wave after leaving the wires. We may consider the case as though the wires were continued past the end condenser, by a pair having a different capacity S_3 per unit length.

Let e_1 be the charge on unit length of the wires due to the incident wave; and e_3 the charge per unit length carried off, with the same velocity v.

Then we may write:

$$C_3 = e_3 v = c e_1 v = g e,$$

where c = coefficient of transmission, and $g = cv$.

$$\text{Now} \qquad e_1 = \frac{C_1}{v} \text{ and } C_1 = \frac{V_1}{Lv}$$

$$\therefore\ C_3 = cC_1 = cV_1 S v$$

Corresponding to the condenser equation we now have

$$\frac{dV}{dt} = \frac{C_{12} + C_3}{S_1} = \frac{C}{S_1} + \frac{cV_1}{S_1 L v}$$

Let $\gamma = \frac{S_1}{S}$, the ratio between the capacities of the end condenser and that of a unit length of the line.

$$\therefore\ \frac{dV}{dt} = \frac{C}{S_1} + \frac{gV_1}{\gamma}; \qquad V = V_1 + V_2 \tag{3}$$

Substituting in this the values given for C and V_1, and developing the equation, we get, letting $t = 0$,

$$n(\phi + \phi') \cos\frac{\delta_1}{2} = - \frac{\phi\left(1 + \frac{g}{\gamma} S_1 L v\right) + \phi'}{S_1 L v} \sin\frac{\delta_1}{2} \tag{4}$$

Letting $nt = \frac{\pi}{2}$,

$$n(\phi - \phi') \sin \frac{\delta_1}{2} = \frac{\left(1 + \frac{g}{\gamma} S_1 L v\right)\phi - \phi'}{S_1 L v} \cos \frac{\delta_1}{2}, \text{ where } \phi' = b\phi \quad (5)$$

We find that the angle of phase difference may be considered as in the second quadrant, the cosines having negative signs. So here if we write the cosine of eq. (4) = − cos. of (5), and at same time make the coefficient of reflection b of (4) equal $-b$ of (5), we can solve between the two equations.

Hence

$$\tan \delta_1 = \frac{-2 L v S_1 n K}{1 - (L v S_1 n K)^2} = \frac{.2 K \gamma \lambda}{K^2 \gamma^2 - \lambda^2} \quad (6)$$

Where $K = \dfrac{1 + b}{1 + b + \frac{g}{\gamma} S_1 L v}$

From (6) we get

$$S_1 = \lambda \frac{S}{K} \left(\frac{\cos \delta_1 + 1}{\sin \delta_1} \right) \quad (7)$$

From this equation the capacity of the terminal arrangement can be calculated from the observed values of S_1 and the wave length λ used.

For λ large compared to γ (as was the case for the wave-lengths used) K is nearly unity for $b = 1$, and for b as small as 0·7, $K = \frac{17}{14}$ only. K is taken as unity throughout.

The value of $S = \frac{1}{L}$ calculated for the parallel wires is ·067 C. G. S. units. For these wires and frequencies any correction terms for S or L, as by Rayleigh's or Heaviside's formulæ, are absolutely negligible, although the resistances for these oscillations are not at all the same as for steady currents.

Formula (7) was applied to the determination of end capacities for the wire ends bare, and again carrying two brass balls, and under varying conditions, for wave-lengths ranging from 60 to 170 centimeters.

The indicator tube was placed across the wires, generally in the second loop from the ends, sometimes in the last (one-quarter wave-length). In the latter position 8^{cm} were allowed for its presence. No bridge could be placed between the tube and the ends in either case, because it was found that the oscillation of any "system" between two successive bridges, was not perceptibly affected by the resonance or non-resonance of any system *behind* it, but only by those between it and the source.

The half wave-length was fixed by two bridges, at the desired distance apart, attached to a strip of wood and always moved together back and forth along the line. The nodes thus located were naturally broader and less defined than when but one bridge was shifted.

Although the whole range of half wave-lengths was attempted, at intervals of $2{\cdot}5^{cm}$, only a few could be satisfactorily observed. This was due to the necessity for a *double* resonance to secure a glow in the tube. The system defined by the two bridges kept one half wave-length apart must be in resonance both with the end system and with the part in front including the exciter.

Had it been feasible to employ much longer wires, 100^{m}, this necessity would not have existed with the limited wave-trains sent out by the exciter.

Regarding the bare ends as two spheres of the radius of the wires, the static capacity as calculated graphically by the methods of inverse points was found to be

$$S_1 = {\cdot}45 \text{ C. G. S.}$$

Thus the actual capacity for the bare ends, for these rapid oscillations, is seen to be very much greater than that calculated for static charges, and varies with the frequency. The curves in Fig. 2 show a slight decrease in the change of phase by reflection with increasing frequency, and a more marked falling off in the end capacity. This decrease in capacity with period is to be expected.

With two brass balls on the ends, $1{\cdot}85^{cm}$ diam., $2{\cdot}55^{cm}$ between centers, the lost length in reflection is of course much more marked. The extreme limits of the balls were here taken as marking the end of the wires.

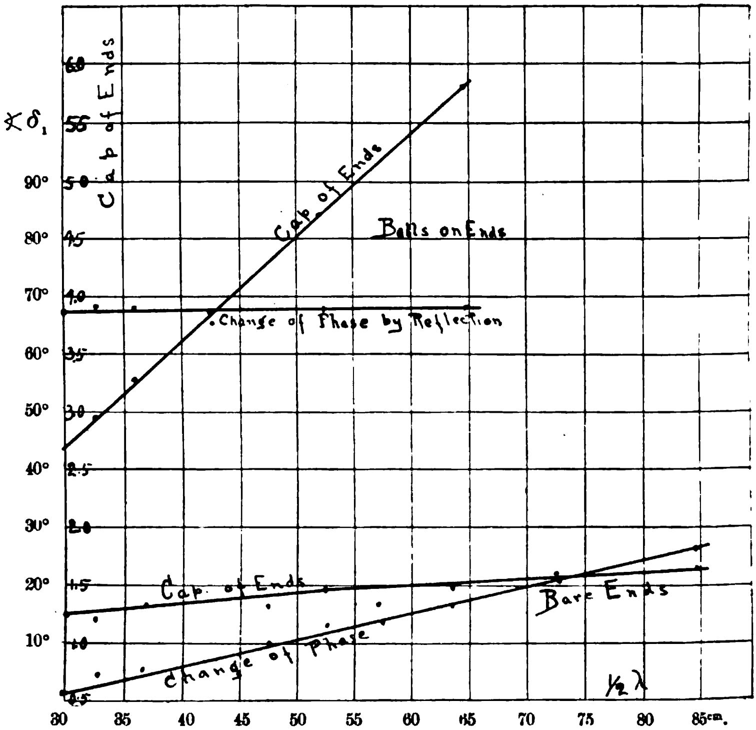
The reflection throughout seemed much better for these balls at ends than for bare ends; the nodes were always more easily located and clearly defined. There was no difference in the character of the reflection with the bare ends, whether these were cut off square or tapered to fine points.

By Maxwell's method the calculated static capacity of the balls is 1·15 C. G. S. units. The observed capacities for these oscillations are from 2 to 5 times greater than this—a much smaller discrepancy than for the case of bare ends. The radiation from the balls is much less.

In the curves given the figures for amounts lost in reflection cannot be defined closer than $\pm 0{\cdot}5^{cm}$, because of the broad nodes found, allowing an error of from 2 to 4 per cent in the angles of change of phase.

As to the reflection from rectangular bends in the wires:—so long as the two wires were kept parallel, there was no perceptible difference or change in the angle of phase. Such corners did not therefore affect to any observable extent the capacities of the end systems, for any frequencies used.

2.

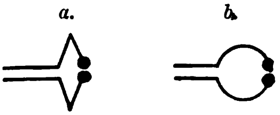


Abscissas represent half wave-lengths, ordinates change of phase by reflection, and capacity of ends.

But when the wires were bent out *from* each other the clearness of node was very much impaired—the greater the angle the less sharp the definition—due to the double reflection then existing.

If the distance between the ends, bare or with balls attached, is kept fixed and a certain section of the wires next adjoining is bent or bowed *out*, from straight and parallel wires into curved or circular forms, the last quarter wave-length is observed to shorten, then increase again. The capacity of the section is changed, until when at last the wires are bent ont and back, as in (*a*), Fig. 3, the capacity may be less than for the original parallel wires; passing through a maximum when the *circular* form (*b*) is taken.

3.

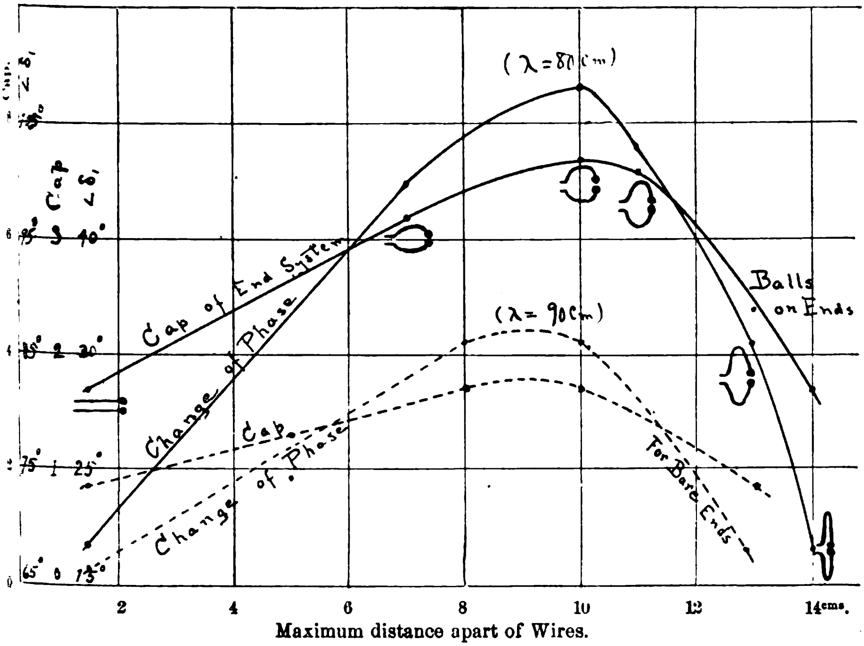


In this case the area also is a maximum.

The same phenomenon was observed for bare ends as for the two balls, though again less pronounced; for a longer section of the wires thus bent the effect is still more marked.

In fig. 4 is shown this relation between the form of the ends and the change in capacity and phase.

4.



Now when such convex bends are put into the parallel wires distant from their ends, the effect is the reverse. Von Geitel* found that they produced a decrease in the capacity of the wires at the point, (as is to be expected from the expressions for the capacity), causing a reflection of the same sign as would a change in wires from thick to thin. By bending the wires in he obtained the opposite reflection. So here it is evidently connected with the terminals. The change of phase is maximum when the ends are close together and still as far removed as possible from the influence of the leading-in wires.

* Wied. Ann., xlix, p. 184.

A peculiarity noticed in the action of the tube was its sluggishness in responding to the waves, it seeming to require at first a strong excitation to enable it to respond to weaker. At the start all bridges were removed before a glow would result. The gas seemed to require a "warming up"—its particles violently excited electrically—before weaker discharges passed.

It was noticed also that if the hand was placed on the wires anywhere, even behind the tube, all glow ceased. The same occurred if the wires were grounded, or a very large capacity attached. Yet here the tube was subjected at least to the incident wave, and theoretically, since a large capacity on both wires is like a no-resistance bridge, there should be also perfect reflection and standing waves. But the action is as though due to free electricity on the wires. Grounding at any point keeps its potential zero, and a heaping-up of the charges on the wires is impossible. With the electrometer also, no deflection was possible so long as a large capacity was attached to the parallel wires.

The electrometer used carried, suspended by a glass fiber 25^{cm} long, a needle consisting of two small aluminum disks, moving in the horizontal plane. Parallel to, and a few millimeters above each end of this needle, was fixed a similar disk, connected by fine wire to one of the parallel wires. The whole was suspended in a vessel of albolene oil. This liquid answered admirably, affording the right damping quality and dielectric strength.

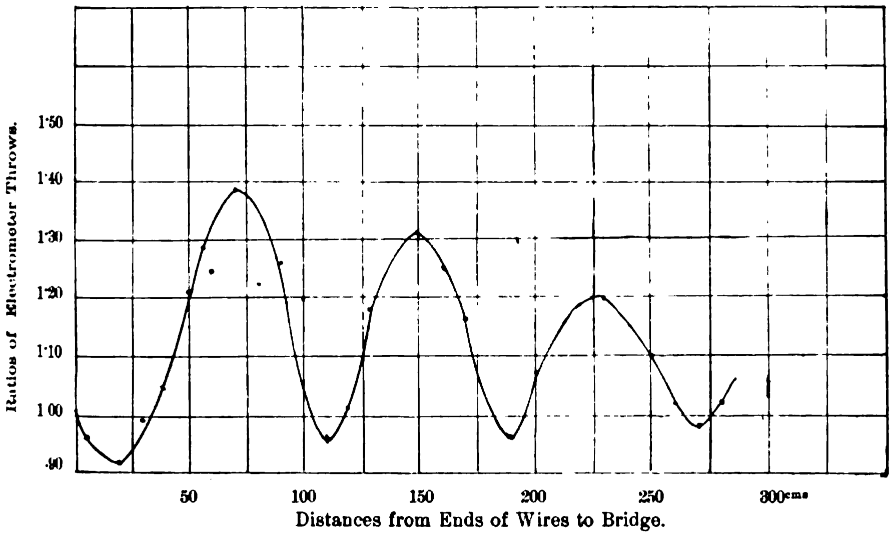
From the center of the needle a fine platinum wire dipped into a small cup of mercury, connected by wire to some capacity. It was found that the deflection was much increased by this, being maximum when the needle was grounded. The sensitiveness of the instrument could thus be directly regulated, and when this leading-out wire was insulated the deflection of the needle charged by induction was almost nothing.

A mirror and scale were unnecessary. A light index arm of glass, 8 inches long, was attached to the upper end of the wooden axis of the needle, where the same joined the glass suspension fiber, above the surface of the oil. This index moved over the face of a mirror scale carrying 120 divisions. The zero was very constant.

For its best working the electrometer did not require the amount of energy in the spark discharge that the glow-tube demanded. The zinc ball gap was made very short, as well as the auxiliary spark gap between the coil and exciter; and the spring interrupter of the coil was adjusted to give as nearly as possible a continuous passage of sparks. The surfaces of this break were kept constantly smooth, as the slightest falling-off of the interrupter, even though unnoticeable to the ear, was at once evidenced by failure of the high-frequency waves.

The decrement of amplitudes in each train of waves here sent out is found to be such that the standing waves created decrease rapidly with increasing distances from the reflecting body. This decrement completely over-masks, in copper wires, that due to attenuation along the wires, for the lengths considered.

5.



This electrometer gave the accompanying curve, fig. 5, similar to those observed by Bjerknes, Barton, and others. As it was impracticable to move the electrometer along the wires the following method was used:—Wires 9·6 meters long were employed and the instrument stationed 4·5 meters from the end. One no-resistance bridge was placed across the wires at a point three-fourths of a natural wave-length beyond the electrometer. This was alternately raised and lowered, so that reflection alternately occurred from it and from a similar bridge moved along the line towards the ends.

The action of the coil is at best so irregular that measurements must be made as nearly simultaneously as possible. First throws of the electrometer needle were read, as much more satisfactory and regular than mean deflections. From 30 to 40 *good* alternate readings were taken for each position of the sliding bridge; the mean ratios of the swings for the two bridges give the relative amplitudes of the two waves. These ratios are plotted as ordinates, and the distances of the sliding bridge from the electrometer as abscissæ. As the distance between the two bridges decreases the discrepancies between throws are seen to diminish, approaching zero. The effective length of the wave-train is about 8 meters.

From this curve the exponential decrement of amplitudes is found to be $x = \cdot 00095$ per cm.

Experiments with the Coherer.

A coherer was used in looking for polarization in the field near the wires. A glass tube half filled with coarse copper filings was placed in the nose of a large zinc funnel, soldered into the side of a tin box. The galvanometer, dry cell, and a graphite resistance of some 150,000 ohms, were shielded in this, leaving only a small aperture through which to read the mirror. Thus protected the coherer responded only to the waves from the parallel wires placed near.

Three gratings were tried: one made of half-inch strips of zinc, alternating with paper; the second, of lengths of insulated copper wire 3^{mm} in diameter, placed as closely as possible; the third, of wires $0{\cdot}6^{mm}$ diameter, strung 5^{mm} apart.

Along the length of the Lecher wires absolutely no polarized displacements were found, whether the coherer lay in the plane of the two parallel wires, or in one perpendicular to this and equally distant from both wires—and whether the coherer were close to or far from these. The waves are propagated in approximately circular forms from the wires, with displacements tangentially perpendicular to them; but there are also displacements parallel to the wires from the flow of the currents in them. One at least of these two components will always penetrate the grating.

That the displacements are not radial here is shown by the complete shielding from them afforded by a tin pipe, as large as 3 inches in diameter, fitted on to the end of the funnel. If this extended more than three inches the action was entirely cut off. This amount of protection was necessary, however, to shield the coherer from diffuse radiation.

The coherer was next placed beyond and facing the ends of the parallel wires (8^{cm} apart). Here also at a distance greater than 15^{cm} from the ends the waves were not polarized, and were cut off as before by a long projecting tin cap. When, however, the ends were brought up close to the grating, or about 8^{cm} from the coherer, a very decided polarization was found. The plane of the two wires being horizontal, the galvanometer gave deflections averaging 17 for the grating strips vertical, and none whatever for them horizontal. This was with the first-mentioned analyzer. The second gave average deflections corresponding to 16 and 2 respectively for the two positions;

the third, deflections 23 to 6 respectively. Rotating the first analyzer, the average results shown in the following table were obtained.

Angle of strips from vertical.	Deflection.	Equivalent deflection.	Cosine of angle.
0°	26	1·0	1·0
22·5°	18	·7	·9
45·0	9	·35	·7
67·5	4	·16	·4
90·0	0	·0	·0

Using two gratings, the segments of the one nearest the coherer lying horizontal, and those of the one in front at an angle of 45° to these, an occasional deflection was secured. More often, however, the resolved vertical component from the first was too weak to penetrate the second. With both gratings vertical good deflections were secured.

Thus the earlier assumption that a beam, as it were, of plane-polarized displacement traveled on beyond the ends of the two wires, was justified. It is also shown very strikingly that it is the component *perpendicular* to the elements of the grating that passes through it. At a very little distance from the ends this plane-polarized beam is lost in the expanding (spherical) waves, or in those diffusely reflected.

Very much might be determined as to the exact nature of the field in the neighborhood of the wires by such use of the coherer—devising proper shields, analyzers, resonators, etc., although as now used it is only roughly quantitative.

My best thanks are due Professor Wright, for the facilities of the Sloane Laboratory put at my disposal, and for kindly interest and valuable suggestions throughout the course of this work, and to Prof. Gibbs for helpful advice.

Sloane Physical Laboratory,
Yale University, May 31, 1899.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Peroxides.*—Some further results have been published by **MELIKOFF** and **PISSARJEWSKY** in their investigations on peroxides. They have shown that acid peroxides may form salts with alkali peroxides. The resulting soluble salts, such for example as the sodium and lithium salts of peruranic acids, when treated with aluminum hydrate are converted into the free acid and hydrogen peroxide. The insoluble salts, such as the barium salt of peruranic acid, when treated with carbon dioxide, act like barium peroxide; barium carbonate, hydrogen peroxide, and peruranic acid being formed. Acid peroxides RO_4 have been obtained from elements belonging to six groups. The stability of the salts formed by them with alkali peroxides decreases with the atomic mass of the element forming the acid peroxide. With metallic peroxides, strongly acid peroxides do not form salts but decompose them, forming hydrogen peroxide. They assign to the peroxy-acids and the metallic peroxides the constitution $HO-OH$ analogous to that of hydrogen peroxide, as they behave similarly with certain reagents. They yield hydrogen peroxide on treatment with dilute sulphuric acid, but if the acid is concentrated many of them yield ozone. Water decomposes the peroxy-acids as it does the peroxides; sodium perborate for example being partially decomposed into sodium metaborate and hydrogen peroxide. The peroxy-acids also behave like the metallic peroxides when treated with manganese peroxide, oxygen being evolved rapidly in the case of soluble salts and slowly in the case of insoluble ones; the peroxy-acids oxidize alkalis, easily converting them into peroxides.—*Zeitschr. Anorg. Chem.*, xviii, 59–65, 1898.

G. F. B.

2. *On the Preparation of Iron Silicide.*—The fact has been observed by **LEBEAU** that copper silicide in the melted state dissolves iron silicide very readily. And upon this he has based a method of preparing the latter compound. Commercial copper silicide, coarsely pulverized, is mixed with ten per cent of iron filings, the mixture is placed in a carbon crucible and this is inserted in an electric furnace supplied with a current of 950 amperes at a pressure of 45 volts, for from four to five minutes. A button is thus obtained, white in color and having a crystalline fracture. It is coarsely pulverized and treated with diluted nitric acid, the temperature being raised toward the end. The copper silicide is dissolved and crystals of iron silicide remain surrounded by gelatinous silica. To remove this, the crystals after washing are heated with a solution of caustic soda. Repetition of the treatment with nitric acid and with soda gives the iron silicide pure. It has the composition $SiFe$, thus differing from the silicide $SiFe_2$ prepared by Moissan by the direct union

of iron and silicium in the electric furnace. It is in the form of tetrahedral crystals having a density of 6·17 at 15°. They scratch quartz but not corundum. Iron silicide is not attacked by oxygen or hydrogen at a red heat, but chlorine, bromine and fluorine act upon it at a red heat with incandescence. Mineral acids are without action upon it, but fused alkalis, or a mixture of fused nitrate and carbonate, attack it readily.—*C. R.*, cxxviii, 933–936, April, 1899. G. F. B.

3. *On an Application of the Equilibrium Law to the Formation of Oceanic Salt Deposits.*—An investigation has been undertaken by VAN'T HOFF AND MEYERHOFFER for the purpose of determining theoretically from the law of equilibrium the order of deposition of salts in consequence of the evaporation of sea water, with especial reference to the Stassfurt beds. Evidently, the relations of the individual salts present to each other have to be first considered, and the present paper considers the solubility curves of the various hydrates of magnesium chloride at temperatures varying from −33·6° to +186°, the point when hydrogen chloride begins to be evolved. The complete equilibrium curve for magnesium chloride and water may be divided into the following portions: (1) Stable solution in equilibrium with ice, from 0° to −33·6°; (2) Stable solutions in equilibrium with the following hydrates, $MgCl_2.(H_2O)_{12}$ from −33·6° to −16·8°; $MgCl_2.(H_2O)_8$ from −16.8° to −3·4°; $MgCl_2 (H_2O)_6$ from −3·4° to 116·67°; $MgCl_2.(H_2O)_4$ from 116·67 to 181°; $MgCl_2.(H_2O)_2$ above 181° or 182°; (3) labile solution in equilibrium with $MgCl_2.(H_2O)_8(\beta)$ from −17·4° to −9·6°. Labile continuations of the curves for the hexahydrate and the dodecahydrate can be obtained, meeting at −30°, whilst similar continuations of the ice and octahydrate equilibrium curves cut at −50°. The dodecahydrate was previously unknown and is best produced by cooling a solution containing a little more water than is required for the crystals, to about −20° and then inducing local over-cooling by solid carbon dioxide. The stable and labile octahydrates also previously unknown can be produced in a similar manner by cooling a solution of the composition $MgCl_2.(H_2O)_{11}$. Once formed, the labile hydrate might remain unchanged for a whole day, but its production could not be depended on. The values found for the solubility of the hexahydrate were in general slightly lower than those of other observers, probably owing to more complete freedom from calcium chloride.—*Zeitschr. physikal. Chem.*, xxvii, 75–93; *J. Chem. Soc.*, lxxiv, 564, December, 1898. G. F. B.

4. *The Spirit of Organic Chemistry, an Introduction to the Current Literature of the Subject;* by ARTHUR LACHMAN. 12mo, pp. xviii + 229. New York (The Macmillan Company).—This book, which is intended primarily as a supplement to text-books of organic chemistry, consists of nine excellent essays upon the development of some of the most important problems of the science. The subjects dealt with are, the constitution of rosani-

line, Perkins reaction, the constitution of benzene, the constitution of acetoacetic ether, the uric acid group, the constitution of the sugars, the isomerism of maleïc and fumaric acids, the isomerism of the oximes, and the constitution of the diazo compounds. The work will be useful as a source of information regarding the history and present status of these particular topics, and it will be valuable also in giving the student a clear idea of the objects of chemical research, and arousing his interest in the literature.

H. L. W.

5. *Lehrbuch der Allgemeinen Chemie.* Von Dr. WILH. OSTWALD. Zweiten Bandes, Zweiter Teil: Verwandtschaftslehre. Vierte Lieferung: Bogen 39–52 Mit Figen 71–152. Zweite umgearbeitete Auflage. Leipzig, 1899 (Wm. Engelmann).—Some of the earlier parts of this fundamentally important work have been already noticed in this Journal, and those interested are well acquainted with its scope and value. The present Fourth Part (pp. 625–828) discusses the cases of Chemical Equilibrium of the Second Order. The part following is to contain those of the Equilibrium of the Third and Higher Orders, and with this the second part of the second volume will be brought to a close.

6. *Insulators for Heat.*—Walter Hempel has made a comparison of the relative value of different media for heat insulation, and gives the following table:

Temperatures in the interior of the vessels.

	Duration of time in minutes						
	5	32	58	88	115	160	207
Dry, clean sheep's wool (dried at 100°)	−74	−63	−61	−50			
Cotton wool	−76	−63	−56	−43			
Silk	−76	−65	−58	−48			
Moist sheep's wool	−76	−64	−54	−44			
Clean wool, air dried	−77	−74	−64	−55			
Eider down	−78	−76	−67	−66	−49	−33	−17
Vacuum tubes of D. Bender and D. Holbein I	−66	−67	−49	−32	−8	+2	+8
Vacuum tubes of D. Bender and D. Holbein II	−68	−65	−49	−34	−11	+1	+8
Weinhold-Dewar tubes—Silvered	−78	−77	−74	−70	−64	−59	−50

It thus appears that carefully exhausted vessels give a better means of heat insulation than any other means, while partially exhausted vessels are inferior to the other means in the above list.—*Wied. Ann.*, No. 5, 1899, pp. 135–138.

J. T.

7. *Optical relations of Gold and Platinum layers.*—This is an examination of the work of various investigators and a study of the best method of making the measures. The author, G. BREITHAUPT, finds that a method by Schmidt permits of the measure of the index of refraction of metals. Gold gives the most constant values, while platinum does not give consistent ones. Mirrors of obsidian proved of value as foundations for the layers. Burned-

in gold showed normal dispersion, while burned-in platinum exhibited anomalous dispersion. Steel and nickel-steel showed anomalous dispersion; brass, highly polished, normal dispersion.—*Wied. Ann.*, No. 5, 1899, pp. 46–73. J. T.

8. *Electrical Waves.*—Albert Neugschwender has described a new method of detecting electric waves, which consists in using as receiver two pieces of tin foil separated by a fine line. This Rhigi resonator is placed in one branch of a Wheatstone bridge. The fine line is moistened by various electrolytes or by vapors. When the electric waves impinge on the slit its resistance is greatly increased, in some cases rising from 80 to 90,000 ohms. The author has carefully investigated the phenomena, and finds that the waves disturb the formation of fine filaments of metal in the electrolytes (Metallbäumchen), which are essential for good conductivity.—*Wied. Ann.*, No. 5, 1899, pp. 92–98. J. T.

9. *Ether Movements.*—G. Mil discusses analytically the question of the fixed and moving ether in relation to Poynting's hypothesis. In order to ascertain a possible limit, he arranged condensers in a powerful magnetic field in such manner that the electrostatic lines of force were at right angles to the magnetic lines, and by means of an interferential refractometer tested whether a light ray suffered any change in velocity. A negative result was obtained. This, according to the author, does not show that the ether is fixed, although the value for μ (inertia of ether particles) was $\mu > 10^{-10}$, which is very small.—*Wied. Ann.*, No. 5, 1899, pp. 129–134. J. T.

10. *Verhandlungen der Deutschen Physikalischen Gesellschaft.*—Physicists will be interested in the announcement recently made by the publishing house of Johann Ambrosius Barth, in Leipzig, that it is proposed to publish the Transactions of the German Physical Society, successor to the Physical Society of Berlin, in successive numbers, published as called for, and for which an annual subscription price of 4 marks will be charged. The first number (pp. 1–48) has already been issued.

II. Geology and Mineralogy.

1. *United States Geological Survey, Eighteenth Annual Report*, 1896–97.—The bound volumes of the Eighteenth Annual Report have been issued in five volumes. Part I, *Director's Report*, including *Triangulation and spirit leveling*, pp. 440. Part II, *Papers chiefly of a theoretic nature*, pp. 653. Part III, *Economic geology*, pp. 861. Part IV, *Hydrography*, pp. 756. Part V, *Mineral resources of U. S. for* 1896. Each of the volumes is illustrated by numerous plates and maps. The contents of the second volume have in part been already noticed in this Journal, as they were issued in pamphlet form. Special notice at this time should be drawn, however, to a few not heretofore mentioned:

The Triassic formation of Connecticut, pp. 1–192, plates 1–20; by W. M. Davis.—This is the final report of Professor Davis on the Triassic area, which he has been studying for a number of years, the main facts and theories of which have already become well known to geologists. The final volume is beautifully illustrated, and is particularly valuable for the photographic representations of several contacts between the trap and the sedimentary rocks, and the clear, systematic presentation of the whole subject.

Glaciers of Mt. Rainier, with a paper by G. O. Smith *on the rocks of Mt. Rainier*, pp. 349–423, plates lxv–lxxxii; by I. C. Russell.—This is a beautifully illustrated account of a glaciated mountain region in Washington, which presents some remarkable features that should attract visitors and sight-seers, as well as the professional geologists.

Geology of Cape Cod District, pp. 497–593, plates xcvii–civ; by N. S. Shaler.—In this paper Professor Shaler gives, in a graphic manner, an account of the superficial geological structure of the district about Cape Cod, tracing the features back to their supposed causes, viz: glaciation, erosion, etc.

Recent earth movement in the Great Lakes Region, pp. 595–653, plate cv; by G. K. Gilbert.—Mr. Gilbert elaborates some of the later results of his studies of the earth movements as affecting the Lake Regions. He has shown the methods of recording observations, and given comparisons of movements in relation to Lake levels, and has drawn together the various observations and reduced them to a form expressing differential movements of the whole region, estimating the rate and direction of past and present movements. (See this Journal, March, 1899, p. 239.)

In the volume of *Economic Geology* are several very valuable reports. The first two, on the Gold fields of Alaska, respectively by Messrs. Becker, and Spurr and Goodrich, have already been noticed in these pages.

Four other important papers are given: Some Coal fields of Puget Sound, pp. 393–436, plates lii–lxviii, by B. Willis; Geology and mineral resources of the Judith Mountains of Montana, pp. 437–616, plates lxix–lxxxvi, by Messrs. W. H. Weed and L. V. Pirsson; The mining districts of the Idaho Basin and the Boise Range, Idaho, by Waldemar Lindgren; with a report on the fossil plants of the Payette formation, by F. H. Knowlton, pp. 617–744, plates lxxxvii–cii; Preliminary report on the mining industries of the Telluride quadrangle, Colorado, pp. 745–850, plates ciii–cxviii, by C. W. Purrington. W.

2. *Nineteenth Annual Report of the Director of the United States Geological Survey*, 1897–98, Charles D. Walcott, Director, pp. 1–143, plates i–ii.—The Director's report of operations for the year 1897–98, and contents of the final report, is in hand. The operations of the Survey are a continuation of those of last year, with very slight modification in general. We note a few important results in the course of the report, reported by the

several members of the Survey. The aggregate appropriation for the Geological Survey for this year was a little over one million dollars.

In Mr. Emmons's report on work in the Rocky Mountain Region, the following results regarding the Tintic mining region of Utah are reported:

"Contrary to what is usually the case in Western mining districts, there appears to have been no genetic connection between ore deposition and eruptive action, for it has been proved that the most important ore bodies—viz., those entirely inclosed in sedimentary rocks—were formed and eroded before the igneous rocks were erupted."

"The complete independence of the ground-water level in the mine in sedimentary and those in igneous rocks."

"As a consequence of the depth of the permanent water level in the former mines, their ores have been very largely oxidized, and in this process of oxidation there has been a remarkable separation of the minerals according to their metallic bases, lead ores predominating at one point, copper ores at another, and silver ores at a third."

Mr. Lindgren reports, regarding Surveys in the Snake Valley, the following:

"This reconnaissance was carried on near the line where the great Columbia lava flows rest against the older ranges of granite and slate in the Idaho side, and showed that the cause of the great fresh-water lake was to be found in the immense lava masses barring the comparatively narrow outlet of a wide pre-Neocene valley. It was also found that since Neocene times the Snake and Salmon rivers have cut gorges from 4,000 to 6,000 feet deep through these lava barriers, equaled in grandeur by few canyons of the West." In the Silver City mining district "transformation or pseudomorphism of a primary gangue mineral, probably calcite, to quartz was noted." Also, "quartz deposits were found carrying gold and silver and at the same time including imprints of vegetable organisms—a proof of their aqueous origin."

Mr. Turner finds in the Yosemite region evidence of "two periods of ice expansion, with an interglacial period."

The Director having, in his capacity as inspector of forest reserves in the northwest, made examination of the Yellowstone, recommends, in his report to the Secretary of the Interior, the construction of new roads from the Grand Canyon Hotel, down the river to Yancey's and thence around the Cook City road; and also several horse trails for the convenience of those who would go on horseback off from the traveled road to points of interest. Another important recommendation is that a hotel be built at the Upper Geyser Basin for the convenience of travelers; and another important suggestion that some means be taken to allay the dust nuisance on the traveled roads in the park.

Mr. Day's report on the Division of Mineral Resources shows a grand total of mineral products of the United States for 1897 to be $632,309,565, "the greatest in the history of the country. A noticeable feature of this remarkable total is the increase in the value of almost all the important metallic products, especially that of pig iron, gold, copper, lead, and zinc, each of the three latter metals reaching their greatest production. Proportionately aluminum made the largest increase, its product being over three times that of 1896 and many times greater than in any year prior to 1895." W.

3. *Pre-Cambrian Fossiliferous Formations;* by CHARLES D. WALCOTT, Bull. Geol. Soc. America, Vol. 10, pp. 199–244, pls. 22–28, 1899.—Mr. Walcott has brought together in this valuable contribution more information than most geologists would suppose to be in existence regarding clastic formations, clearly pre-Cambrian in position, and yet as clearly of sedimentary origin, and probably fossil-bearing, situated in various regions on the North American continent. The discussion of the section of the Belt terrane in Montana is the result of special investigations of the author during a recent trip in that region. The author has gathered the facts from reports already made by others, bearing on this subject, and in discussing the evidence of fossils in strata determined to be of pre-Cambrian age, makes reference to foreign as well as American evidence. The principal evidences brought forward are the following: Of problematic character is Eozoon, whose organic origin is as yet unproven. The same appears to be true of supposed fossil sponges, described by Matthew, from Laurentian rocks of New Brunswick, and of radiolarians and sponges of Brittany.

Graphite has frequently been cited as proof of the existence of fucoids, and the finest example of bedded graphite in Algonkian rocks referred to is at the mines of Hague, on Lake George, New York, where graphite occurs, presenting the appearance of fossil coal beds, and alternating with sandstones. The graphite shale exists, varying from 3–13 feet in thickness.

The supposed organic origin of Paleotrochis is shown to be erroneous by recent investigations of Mr. Diller, as reported in this Journal (May, 1899, p. 337).

Again, the evidence brought forward by Mr. Gresley, of supposed organic remains in the iron-bearing rocks of the Menominee range, Michigan, and described as actual evidence of life, and other evidence of similar kind in these Upper Huronian rocks, have been shown to be of doubtful value upon minute examination.

The Aspidella of the Avalon terrane of Newfoundland is reported by the author as, probably, of organic origin.

The Etcheminian fossils, reported by Matthew, are referred to, without giving judgment in the matter, awaiting the fuller report of the fauna, which is expected soon. Mr. Matthew thinks the fauna contains 20 species.

In the Chuar terrane of the Arizona Grand Canyon series, of established pre-Cambrian age, forms of unquestioned organic origin have been obtained. The one, *Cryptozoon occidentale*, is described by Sir Wm. Dawson; the other is described in the present paper under the name of *Chuaria circularis.* Some others, obscure forms, possibly Hyolithes, are associated with them.

The fossils described from the Belt terrane of Montana constitute the more important contributions of this paper. They occur in the "Greyson shales, in a belt of calcareous shales about 100 feet above the Newland limestone, at a horizon approximately 7,700 feet beneath the summit of the Belt terrane at its maximum development. Indications of fossils were first discovered near the mouth of Deep Creek canyon, a short distance above Glenwood postoffice. Subsequently they were found in Sawmill canyon, about 4 miles above Neihart."

"The fauna includes 4 species of annelid trails and a variety that appears to have been made by a minute mollusk or crustacean. There also occur in the same shales thousands of fragments of one or more genera of crustaceans. All the specimens are very much compressed and flattened, and often large fragments of the test have been broken by a movement in the shale subsequent to their embedment in the mud."

"The most interesting feature of the fauna is the occurrence of undoubted organic remains and the presence of a crustacean of a much higher type than most paleontologists would have predicted for this horizon."

Six new species are described from these shales, distributed in three different genera, one of which is a new genus, referred to the Merostomata. W.

4. *A Palæozoic Terrane beneath the Cambrian;* by Geo. F. Matthew. Annals N. Y. Acad. Sci., vol. xii, No. 2, pp. 41–56, 1899.—This paper describes a series of strata beneath the Cambrian in New Brunswick, Canada, and Newfoundland, which uncomformably underlie that system. The terrane in Canada is in the southern part of the province of New Brunswick, and is exposed in certain valleys by the erosion of the Cambrian. It consists of red and green slates and sandstones, with some conglomerate at the base, and intercalated. In Newfoundland at Smith Sound, on Trinity Bay, and elsewhere, a similar series of strata are found; but here the strata are almost entirely red slates, though limestone beds are intercalated.

In the limestones there is found a fauna which has notable points of difference from the Cambrian. No trilobites have been found in it, but the Hyolithidæ are especially numerous, and for size exceed all other forms of the fauna. Conical shells resembling Palæacmæa and Scenella are common, but other Gasteropods and the Brachiopods are quite small. A small Lamellibranch was found, and a minute crustacean (Aptychopsis). Burrows and trails of worms occur. Attention is called to the advanced development of the Hyolithidæ which are present in this fauna. It is suggested that some of the red slates near Boston, Mass., may be of this age.

5. *The Islands and Coral Reefs of Fiji;* by Alexander Agassiz.—Volume XXXIII of the Bulletin of the Museum of Comparative Zoology at Harvard College has recently been issued, containing a description of the coral reefs of the Fiji Islands by Professor Agassiz, as the result of the investigations begun by him in November, 1897. A paper by the author published in this Journal for February, 1898, gave a summary of his observations, and states clearly the most important point arrived at, namely, his conclusion that the theory of Darwin is inapplicable to these islands. All interested in this fundamental problem will turn with pleasure to this exhaustive monograph, with its beautiful series of one hundred and twenty plates. The earlier of these represent the forms of the islands with their outlying reefs, while nearly one hundred are artotype reproductions of photographs, giving a charming impression of the peculiar features of the beautiful scenery. While this notice can serve only to call attention to the publication of this paper, it may be worth while to quote the concluding paragraph by the author, in which he summarizes the conclusions he has reached:

"My observations in Fiji only emphasize what has been said so often, that there is no general theory of the formation of coral reefs, either of barrier reefs or atolls, applicable to all districts, and that each district must be examined by itself. At least such has been my experience in the Bermudas, the Bahamas, Cuba, Florida, the West Indies, the Sandwich Islands, and Australia. The results of this trip show plainly that Darwin's theory is not applicable to the Fiji Islands, notwithstanding the borings at Funafuti, and that, in all cases I have examined, the reefs form but a thin crust upon the underlying base, the shape and composition of which is not in any way due to the growth of corals of the existing period."

6. *Experimentale Untersuchungen ueber die Bildung der Minerale im Magma von* J. Morozewicz. Tsch. Min. Petr. Mitth., xviii, Nos. 1, 2, 3, 1898.—By their publication in German the important investigations which Morozewicz has been conducting for five years or more and which, as heretofore published in Russian, have been inaccessible to most petrographers and chemists, are now available for use and study.

Not since the now classic studies of Fouqué and Michel-Lèvy has so important a work appeared on the formation of minerals in molten magmas. The author obtained the use of a portion of one of the furnaces in a glass factory and was enabled to conduct his experiments under conditions and on a scale which no previous experimenter had been enabled to command. For the actual results themselves the original work must be consulted, they are too numerous and important to admit of mention in a brief notice. Among others, most of the natural lavas, including rhyolite, as well as a large number of minerals, some of them supposedly foreign to igneous magmas, were produced. The minerals of granite rocks, quartz, feldspar and mica, were formed in dry fusion. Many laws concerning the formation of minerals in certain chemical compositions by fusion are announced. It is a work which should be carefully studied by every petrographer, mineralogist and mineral chemist. L. V. P.

7. *Kyshtymite and Corundum-Syenite.*—In the work mentioned above MOROZEWICZ describes massive rocks from various localities in the Urals containing corundum. Some of these are corundum-syenites consisting mainly of orthoclase, biotite and corundum—the latter playing the function of quartz in a granite. Some are pegmatitic in character, the well-formed corundum crystals surrounded by orthoclase. Such occurrences must resemble the corundum-syenites of Ontario which have recently attracted much attention. Corundum-syenite-pegmatite occurs also in Montana at an undescribed locality, while Mallet in a recent work (Records Geol. Surv. India) describes instances of corundum in syenitic rocks as well as basic ones, and these latter recall the North Carolina localities. The occurrence of corundum as an important constituent of igneous rocks is now not only well confirmed but proving not uncommon.

Morozewicz describes also from the Urals rocks which consist of corundum and biotite with some zircon and spinel and of granitic structure. The alkali feldspars are here replaced by plagioclase and for these plagioclase-corundum rocks he proposes the name of Kyshtymite. It is the source of the disputed barsowite of Rose, which is here shown to be anorthite. L. V. P.

8. *Le Gabbro du Pallet et ses Modifications*, by A. LACROIX. Bull. des services Carte géol. de France, No. 67, vol. x, 1899, 8°, pp 56, Paris.—The author in this work describes a massif of gabbro surrounded by mica schists. It is formed in the main of an olivine-gabbro with labradorite which passes gradually into norite with andesine and cordierite, especially at the borders. It is cut by numerous dikes whose rocks recall those associated with the gabbros of the Odenwald. The chief interest centers in the origin of the norite with cordierite and garnet, and this is believed to be the result of the normal gabbro coming in contact with the mica schists and absorbing them in quantity with consequent change in chemical composition and production of a different mineralogical type. L. V. P.

9. *Steinbruchindustrie und Steinbruchgeologie;* by O. HERRMANN. 8°, pp. 428, pl. 7. Berlin, 1899.—This work, which is written for those using stone in technical ways such as quarrymen, architects, engineers, etc., gives in a rather simple and elementary manner a description of the chief rock-making minerals followed by an account of the most important rocks from a technical standpoint, the descriptions and classification being based on Zirkel's manual. A considerable amount of geology relating to the subject is incorporated. This is followed by a description of the tools and methods of quarrying and working stone.

The succeeding and larger part of the volume is devoted to a minute description of the quarries and stone industry of the kingdom of Saxony.

The volume should answer the same purpose in Germany that the admirable hand-books of Merrill have done in this country.

L. V. P.

10. *Studies in the Amphiboles and Pyroxenes.*—Attention must be called to two important articles published by R. A. **Daly** in the *Proceedings of the American Academy*, volume xxxiv. The first (pp. 311–323) gives a minute discussion, with several plates, of the optical characters in the vertical zone of amphiboles and pyroxenes, showing with this a new method of determining the extinction-angles from cleavage plates.

The second, a larger paper (pp. 373–429, pl. i–iv), takes up the subject of the etching figures of these minerals, particularly those of the amphibole group. The care with which the author has worked out the special conditions necessary to obtain the best results and the fullness with which he describes his experiments, make his paper of great value to all interested in this subject, aside from the conclusions which he has deduced. Among other points he proves that the amphiboles are throughout holohedral. He also shows that this method of investigation serves to exhibit the close relationship existing between the different members of the group, as too between them and the corresponding pyroxenes. Further, it emphasizes the distinction between the non-aluminous and aluminous amphiboles, usually insisted upon in works on mineralogy, and at the same time shows the great importance of a sesquioxide, whether ferric oxide or alumina. In regard to certain members of the amphibole group, the following conclusions are given:

"Glaucophane and gastaldite are the same species, and both isomorphous with hornblende. Arfvedsonite appears to hold a more or less independent place in the family of amphiboles. Barkevikite is more closely related to common hornblende than to arfvedsonite. Anthophyllite and gedrite are plainly orthorhombic and holohedral. Aenigmatite diverges considerably from the amphibole habit, but betrays a tendency toward symmetrical cohesional property, as it does toward crystallographic symmetry." Incidentally the author has found an amphibole so peculiar in etching figures that he has separated it as a special variety under the name *philipstadite*. (See p. 83.)

11. *Brief Notices of Some Recently Described Minerals.* **Hardystonite** is a new calcium-zinc silicate from Franklin Furnace, New Jersey, described by J. E. Wolff. It occurs in granular crystallized form, showing several cleavages interpreted as basal and prismatic. Thin sections show it to be uniaxial and negative. Hardness, 3 to 4; specific gravity, 3·396; colorless to white, with vitreous luster. The formula deduced is $Ca_2ZnSi_2O_7$, obtained from a number of analyses, of which one is here quoted.

SiO_2	ZnO	MnO	CaO	MgO	Fe_2O_3	ign.
38·10	24·30	1·50	33 85	1·62	0·57	0·52 = 100·46.

Before the blowpipe it fuses with difficulty to a cloudy glass, giving a red calcium flame; on charcoal it glows and yields a sublimate of zinc oxide; gelatinizes easily with hydrochloric acid. Obtained from the North Hill mine at Franklin, where it occurs in a fine granular banded ore associated with willemite, rhodonite and franklinite. Named from the township in which the locality is situated.—*Proc. Amer. Acad. Sci.*, xxxiv, 479, 1899.

Carnotite is a vanadate of potassium and uranium described by C. Friedel and E. Cumenge. It occurs as a yellow crystalline powder, or in loosely cohering masses, easily separated by the fingers; it is intimately mixed with a quartzose sand. The formula given for it is $K_2O.2U_2O_3.V_2O_5.3H_2O$, deduced from the following analyses (after the separation of silica) of air-dried material:

V_2O_5	U_2O_3	K_2O	H_2O	
20·12	63·54	10·37	5·95 = 99·98	
20·31	64·70	10·97	5·19	Fe_2O_3 0·96 = 102·13
19·95	62·46	11·15	—	Fe_2O_3 0·65

Occurs in Montrose Co., Colorado, in cavities or associated with malachite and azurite. Some samples show 60 p.c. of SiO_2, the purest 2·6 to 7·2 p.c.; separation is accomplished by nitric acid. Named after M. Adolphe Carnot.—*Comptes Rendus*, cxxviii, 532, 1899.

Philipstadite is a variety of amphibole named by R. A. Daly, and identified by him in the course of an investigation of the etching figures of the amphiboles, which is referred to in another paragraph (p. 82). The locality is Philipstad, Sweden. It shows anomalous etching figures on *m* (110) and *b* (010); pronounced zonal structure; small optic axial angle (about 50°); also unusual pleochroism and absorption: viz., $\mathfrak{a}$ light brownish green, $\mathfrak{b}$ dark yellow-green, $\mathfrak{c}$ dark blue-green; $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$. It is optically —, with an extinction-angle on *b*(010) with $\acute{e} = +15° 9'$ (Na). An analysis by Pisani gave:

SiO_2	TiO_2	Al_2O_3	Fe_3O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	ign.
45·20	0·84	7·34	7·55	15·80	1·52	12·30	8·40	0·80	0·37	0·70 = 100·82

—*Proc. Amer. Acad. Sei.*, xxxiv, 433, 1899.

Federovite is a pyroxene, intermediate between ægirite-augite and ægirite. It is named by Viola in a petrographical article on rocks from the province of Rome, Italy, in which the author makes an extended study of the optical properties of the pyroxenes. In this he shows that they may be classified into groups according to the angle, $c \wedge \mathfrak{c}$ which angle increases with increasing soda and iron. Of those in which $c \wedge \mathfrak{c} = 50°–56°$ and $2V = 50°$ are called aegirite-augite, he thinks that those in which $c \wedge \mathfrak{c} = 65°–75°$ and $2V = 50°$ should have a separate name. Such a variety would contain from 9–13% alkali, about 24% iron oxide and strong pleochroism $\mathfrak{c}$ = yellow, $\mathfrak{b} = \mathfrak{a}$ = olive green. The name given above, which is proposed for this variety, is given after the Russian petrographer E. von Federov.—*Jahrb. f. Min.*, i, 120, 1899.

12. *The Characters of Crystals; an Introduction to Physical Crystallography;* by ALFRED J. MOSES. Pp. 21, New York, 1899. (D. Van Nostrand Company.)—Professor Moses has here developed and presented in book-form a series of chapters on the Geometrical and Physical Characters of Crystals, the substance of which has already appeared in the School of Mines quarterly. The first part of the work is devoted to the geometrical side, and after a brief historical summary, there is given an account of the general properties of crystals, followed by a discussion of the thirty-two groups divided according to symmetry. Here the order, method and nomenclature of Groth are followed closely. The latter half of the work is devoted to physical characters, those relating to light occupying by far the larger portion of the space. The presentation throughout is concise and in the main simple; many students will find the work interesting and helpful, for it does not assume a special knowledge of Mineralogy.

III. BOTANY.

1. *Variation under grafting, and the heredity of acquired characters;* by L. DANIEL. *Ann. sc. nat., April and May,* 1899.—M. Daniel has conducted his interesting studies in regard to the effect of the scion on the stock and the origination of variation thereby, for almost ten years. He has made his work logically comparative, and has, in this way, contributed some very important facts to the literature of the subject. He insists that a broad distinction must be drawn between the behaviour of a cutting and an implanted graft. The former has in the soil the nutritive conditions of its parent; the graft is tributary at once to the stock in which it is fastened and places it at once under contribution. It is not a matter of parasitism, for the scion, with its leaves, is to aid in providing elaborated matters for the stock, but, nevertheless, it demands crude materials from the soil through and from the stock.

The graft and grafted plant must be regarded as a case under the general law that change of environment may, or rather, must modify form and structure. Variation from grafting is a function of modifications brought about in the general nutrition of the two plants. This modification may be direct as in the case of the somatic union, or indirect as in the instance of the blending of the germ-plasma from two sources. The author makes the statement that the germ-plasma can be affected from the first generation in the graft, contrary to the law laid down by Weissmann.

The graft and stock introduce variations which may be very slight and liable to be overlooked, but carefully considered these variations are seen to be generally conservative. And as the graft can convey in perpetuity an accidental variation, these accidental variations of the second order can themselves be transmitted effectively. If the influence of a graft on a plastic soma may be strong enough to lead to the origination of a variety, as this research has shown to be possible, we have here in the process of grafting a valuable appliance which is capable of wide utilization in initiating new forms as well as in preserving old ones. The action of grafting on the reproductive elements and on the transmission of these new characters opens up to seed cultivators an inviting field of practice. It must not be overlooked that, as matter of fact, variation does not come in the grafted plants themselves, but manifests itself in the embryo alone. The author emphasizes the importance of this process of grafting in the improvement of sorts, and shows that such work can be carried on with the utmost system. The process is. by no means, confined to woody plants, but, as the investigation shows abundantly, it is applicable to a wide range of herbaceous species. Merely from a utilitarian point of view, the research is a valuable contribution, while regarded from a purely scientific standpoint it possesses deep interest. The work already done is of consequence, but its best service is in opening up new practical questions. G. L. G.

2. *Researches concerning certain features in the appropriation of nitrogen by plants;* by L. LUTZ. *Ann sc. nat., Jan. and Feb.*, 1899.—After a good, although brief, resumé of the more important studies in regard to the relations of plants to nitrogen, the investigator gives a detailed account of his own researches in one part of the field. His results are claimed by him to prove that placed under as aseptic conditions as possible, and also under conditions which forbid ferment action or the fixation of free nitrogen, phanerogamic plants can borrow from *amines* employed in the form of salts, all the nitrogen which is necessary for their use. And, further, he decides that the assimilation of these substances can take place without having their nitrogen previously brought into nitric or ammoniacal combination. There is, however, a condition requisite, namely: that the *amines* arise from the substitution of hydrogen in radicals which do not possess too great size of molecule; thus, the methylamines are excellent sources of assimilable nitrogen, while benzylamine and pyridine are inadequate. The phenol amines are tonic.

The salts of the compound ammoniums and the alkaloids, employed as the exclusive source of nitrogen, do not furnish enough to plants; on the contrary, plants under these conditions may even lose a part of their initial nitrogen. This loss may be interpreted, according to the author, as due to a sort of auto-fermentation.

One of the most interesting facts noted by M. Lutz is the ready absorption of unassimilable alkaloids in the presence of assimilable nitrogen. Possibly, he says, this may throw light on the cause of the migrations and disappearance of alkaloids in the plant at certain epochs of its life.

The whole series of experiments on three classes of plants, Phanerogams, Algae, and Fungi, shows that these organisms are capable of appropriating the lower animes as well as the nitrates, and this conclusion is emphasized as explaining the rapidity with which plants can utilize manures. The author points out the difficulty of conducting such experiments on phanerogams, but the results thus far are the same as those obtained by study of fungi, which can be more easily managed. G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—The preliminary announcement of the forty-eighth annual meeting of the American Association has recently been issued. The meeting will be held at Columbus, Ohio, August 21st to 26th. The several affiliated scientific societies will also hold their sessions in Columbus. The Association headquarters will be located in room 10, University hall, Ohio State University, and the hotel headquarters of the Council of the Association will be at the Chittenden Hotel. The local secretary is Professor B. F. Thomas, Ohio State University, Columbus, Ohio, who should be addressed in regard to all matters relating to local arrangements, transportation, and hotel and boarding-house accommodations, etc.

The Permanent Secretary, Mr. L. O. Howard, of Washington (Cosmos Club, before August 15, after that date A. A. A. S., Columbus), who issues the circular alluded to, will send copies of it to all desiring information in regard to the presentation of papers, the nominations for membership, etc.

2. *Scientia.*—A new series of small volumes on scientific subjects has been undertaken by G. Carré & C. Naud, as publishers, in Paris. It is intended to present in concise form discussions of scientific questions of importance at the present time with the object of aiding the busy reader and worker to keep up with the bewilderingly rapid progress of science.

The series is divided into two parts,—*physico-mathematical* and *biological.* The character of the work that will be done is sufficiently guaranteed by the names of those that appear as directors in the two departments. They are as follows: In the physico-mathematical section:—MM. Appell, Cornu, d'Arsonval, Friedel, Lippmann, Moissan, Poincaré, Potier. Also, in the biological section—MM. Balbiani, prof. au College de France; d' Arsonval, Filhol, Fouqué, Gaudry, Guignard, Marey, Milne-Edwards.

Three volumes have been issued, whose titles are given below. Among others proposed is one on the Zeeman Effect, by A. Cotton; another on the Determination of the Ohm, by G. Lippmann, etc.

The volumes already published are:—

La théorie de Maxwell et les oscillations Hertziennes. H. Poincaré: pp. 80.

La Spécificité cellulaire. L. Bard. pp. 100.

La Sexualité. F. le Dantec. pp. 98.

3. *Annals of the Astronomical Observatory of Harvard College.* Volume XXXIX, Part I. *Peruvian Meteorology*, 1888 to 1890. Compiled and prepared for publication by SOLON I. BAILEY, under the direction of E. C. Pickering, Director.—This very interesting volume contains an account by Professor Bailey of the establishment, under the auspices of the Boyden Fund, of a meteorological station on the volcano El Misti, above Arequipa, Peru, at an altitude of 19,200 feet. Professor Bailey's narrative is most entertaining and, in connection with the excellent illustrations, gives those who are not so fortunate as to have had the opportunity to attain such an altitude, some idea of the grandeur of the accompanying scenery. A second chapter discusses the configuration and height of the Andes and a third contains a series of tables giving the meteorological observations made in Peru during the years 1888, 1889, and 1890.

4. *Report of the Superintendent of the United States Coast and Geodetic Survey, showing the progress for the year ending June, 1897.*—The annual report of General W. W. Duffield has recently been issued by his successor, Mr. Henry S. Pritchett. It contains the usual statement of the progress made in the Survey work at different points on the coast, with a series of fifteen charts relating thereto. The second part of the volume contains a series of twelve Appendices on various topics, among which we note one on the Distribution of Magnetic Dip and Intensity for January, 1890, by C. A. Schott (second edition, with three charts); another by the same author discusses the telegraphic longitude net of the United States, and its connection with that of Europe from 1866 to 1896. Another contains an account of the Magnetic Observations made in connection with the Greenland Expedition of 1896, under the charge of Professor A. E. Burbon, given by G. R. Putnam. Two highly valuable papers by Rollin A. Harris contain a Manual of Tides in two parts,—the first dealing with the history of the subject, the second with tidal observations, equilibrium theory, and harmonic analyses. The fullness of these discussions and the large number of illustrations make this memoir particularly serviceable.

5. *A Catalogue of* 2,030 *Stars for the epoch* 1895, *with an Appendix giving the derivation of proper motion for* 971 *Stars;* by JERMAIN G. PORTER, Director. Publications of the Cincinnati Observatory, No. 114, pp. 114, 4to. Cincinnati, 1898.—This important catalogue containing a second series of five-year observations, with Cincinnati meridian circle by the Director of the Observatory, J. G. Porter, has recently been issued.

6. *Stars and Telescopes. A Hand-book of Popular Astronomy;* by DAVID P. TODD, Director of the Amherst Observatory; pp. 419, with 244 illustrations, including 82 portraits. Boston, 1899. (Little, Brown & Co.) This book is founded on Lynn's Celestial Motions with copious additions by Dr. Todd, especially in the matter of illustrations. In so long a list there are naturally some to be found which could well enough be spared, as drawings of

the supposed markings of Mercury and Venus, and photographs of such mechanisms as the bolometer in a water-jacket and the 40-foot horizontal photo-heliograph in its shed—the view being taken from outside the shed.

Such superfluities do not detract from the value of the book, which is crowded with varied information most attractively presented. W. B.

7. *Elements of Practical Astronomy;* by W. W. CAMPBELL, Lick Observatory; pp. 264. New York, 1868. (Macmillan & Co.) Based on lectures delivered at Michigan University. A very clear and scientific presentation of as much of the subject as is possible or desirable in training students upon the fundamental principles of telescopic measurements. W. B.

8. *An Introduction to the Mathematical Theory of Attraction;* by FRANCIS A. TARLETON, Professor of Natural Philosophy in the University of Dublin; pp. 290. New York, 1899. (Longmans, Green & Co.) The theory of attraction, which had its origin in physical astronomy, now finds its more difficult and important uses in electricity and magnetism. As the author points out in his preface, the theory of fluid motion, investigated with such far-reaching results by Helmholtz, Thomson and Stokes, has its leading problems mathematically the same as problems in the theory of attraction. The present text-book gives adequate treatment of the theory in its applications to these lines of research. W. B.

9. *Les Variations de Longueur des Glaciers dans les Régions Arctiques et Boréales;* by CHARLES RABOT.—In the number of this Journal for November, 1897, an abstract was given of the first part of a memoir on the above subject, published under the auspices of the Commission Internationale des Glaciers. The opening portion of the second part is now published in the number of the *Bibliothèque Universelle* for April 15th. It is chiefly occupied by a discussion of the glaciers of Spitzbergen as observed by various explorers, and gives many interesting facts in regard to this remote region.

10. *The Odonata of Ohio;* by DAVID S. KELLICOTT, Ph.D. pp. 116. Columbus, 1899. Ohio State University. Contributions from the Department of Zoology and Entomology. No. 1.—This valuable paper by the late Professor Kellicott (died April 13, 1898) has recently been issued. It has been edited by Mr. J. S. Hine, who has completed the parts of the manuscript left unfinished; he has also added a sketch of the author's life and a bibliography. The drawings have been made by Mr. W. E. Kellicott.

11. *Electricity in Town and Country Houses;* by PERCY E. SCRUTTON. Second edition, pp. 148. Westminster, 1898. (Archibald Constable & Co.)—This little volume, of which a second edition is now issued, gives an account of the methods employed in installing electricity in houses, with numerous practical illustrations. Besides the application of electricity to lighting, it also discusses briefly some of the various other uses, as a motor, etc., to which it is adapted.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*Rotatory Polarization of Light in Media Subjected to Torsion;* by ARTHUR W. EWELL.

IT is stated in Verdet's Leçons d'Optique Physique* that F. E. Neumann demonstrated mathematically that the plane of polarization of a linear polarized ray, propagated parallel to the axis of a twisted cylinder, is rotated proportionally to the length of the cylinder and the angle of torsion. Verdet remarks that although this result is probably correct, experimental verification is very difficult and had been sought in vain by Neumann and Drion. In the bibliography at the close of the chapter in which these statements occur, three references are given for Neumann's paper. One† relates to the original memoir, the other two to abstracts containing nothing additional.

In this memoir, from the strains when the torsion is small (and when consequently the cross sections remain sensibly plane), Neumann obtains an equation which gives a rotation of the axes of double refraction proportional to the length of the cylinder and in the same direction as the twist but independent of the magnitude of the twist, for rays at an angle with the axis and whose plane of incidence does not include the axis. If the plane of incidence includes the axis or if the ray is parallel to the axis, his equation gives no rotation of the axes of double refraction. Neumann does not state clearly whether he considers that a rotation of the axes of double refraction implies a rotation of the plane of polarization. A careful search failed to bring to light any memoir by Drion on this subject or any other memoir by Neumann.

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* Vol. ii, p. 389.

† Abhand. d. königl. Akad. d. Wissen. zu Berlin, 1841, Part II.

I have found but one other memoir directly on this subject. In a paper on torsion Wertheim* describes the optical characteristics of twisted glass cylinders. Glass rods, about 30^{cm} long and 2^{cm} square were annealed until they showed only a faint cross when viewed between crossed Nicols. A double refracting plate giving the sensitive tint was placed between the polarizer and the end of the glass bar. If the analyzer was set at right angles to the polarizer, of the four quadrants into which the dark cross divided the cross section of the prism, two diagonally opposite were green and the other two yellow. If the prism was twisted, the cross left the center, which became yellow if the twist was to the right and green if to the left. However, almost identical results were obtained when the bar was simply rotated to the right or left without twist, whence Wertheim concluded that torsion simply produced double refraction, positive or negative, according to the direction of the twist. Wertheim was much disappointed in his experiments and considered that they decided nothing about the properties of perfectly homogeneous bodies subjected to torsion and that they neither verified nor disproved Neumann's mathematical results.

An interesting parallelism with the action of light in a twisted medium is Bose's† experiment in which he found rotation of the plane of polarization of electro-magnetic waves, traversing a twisted cylinder of jute fibres parallel to the axis. If the twist of the bundle of jute fibres was reversed the plane of polarization was rotated in the opposite direction, but Bose does not state whether the rotation of the plane of polarization was in the same direction as the twist or in the opposite direction. The analogy to light in a twisted medium must not be carried too far on account of the great difference in wave length of the disturbances considered and in the character of the media.

I first studied the effect of torsion on the optical properties of a rectangular glass bar made by Duboscq of Paris, 15^{cm} by 12^{mm} by 7^{mm}. The ends of the bar were placed in thin wooden cylinders with rectangular apertures slightly larger than the bar. These cylinders were grasped by iron clamps attached to long levers by which the torsion was applied. The clamps could grasp the cylinders in any position and thus the bar could be studied in different azimuths. This bar showed no dark cross when placed between crossed analyzer and polarizer, but was dark along the edges. The bar was tested in both the Laurent and Scheibler polarimeters, and although the phenomena were not as distinct as was desirable, and varied in amount in different azimuths, there seemed to be an unquestionable rotation of the plane of polarization in the opposite direction to the twist, for rays parallel or nearly parallel to the axis of torsion. Before any careful quantitative measurements had been made the bar became suddenly very doubly-refracting, so that on twisting, the only optical change was a clearing up of the center for all azimuths, suggesting the phenomena observed by Wertheim. Soon after it broke. As this bar originally showed no dark cross, more promising results could have been expected than Wertheim obtained with his glass bars and the observations were certainly very suggestive of rotatory polarization, if not decisive.

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* Ann. de chim. et de phys., iii, l. 1857..

† Proceedings of the Royal Society, vol. lxiii, 1898.

Four circular glass cylinders, 4 to 6^{cm} long and 7 to 8^{mm} diameter, were examined between crossed polarizer and analyzer and all showed the dark cross and rings. One even showed the double set of rings and dark hyperbolæ of biaxial crystalline plates. The best of these cylinders was heated twenty-four hours in a furnace and carefully cooled. Although one end had been partially fused, the cylinder still showed a cross, but fortunately too faint to seriously disturb observations. Thin wooden cylinders were cemented to the ends and could be grasped in any position by clamps attached to long levers. The torsion was applied by weights hung on these levers 18^{cm} from the axis of the glass cylinder. Observations were made in the Scheibler saccharimeter for each twisting moment at azimuth intervals of 45°. In each azimuth five readings were taken.

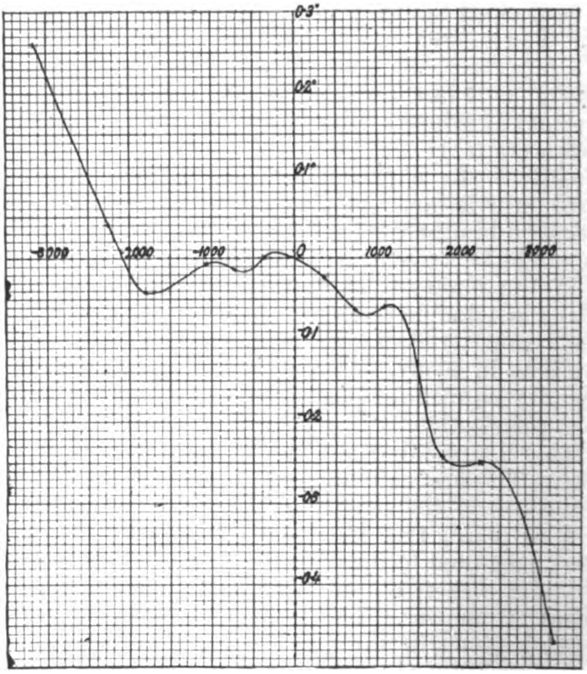
In most of my experiments considerable double refraction appeared on twisting. This would increase in some azimuths and decrease in others the effect of any rotatory polarization which might be present, so that there resulted some irregularity in the observations in different azimuths. Since there is nothing in a double refracting substance to distinguish clockwise and counter-clockwise rotation, if the average of the observations in many different azimuths indicates a distinct rotation of the plane of polarization, the medium must possess rotatory polarization.

In Table I are tabulated the observations with this glass cylinder. The first column gives the number of the experiment, the second the length of the cylinder where the twist could take place, that is, the distance between the wooden cylinders cemented to the ends. After the tenth experiment the cylinder was fractured near one end and when repolished was about 1^{cm} shorter. The twisting moment per centimeter of length is given in the third column in gram-centimeters. The fourth column gives the rotation of the plane of polarization per centimeter of length, after applying the index error of the instrument and reducing the results to angular measure.

TABLE I.

I.	II.	III.	IV.
1	5	0	0°·001
2	"	360	—·022
3	"	720	—·062
4	"	1080	—·060
5	"	1800	—·242
6	"	0	—·006
7	"	—360	·002
8	"	—720	—·014
9	"	—1080	—·006
10	"	—1800	—·042
11	4	2250	—·25
12	"	0	—·12
13	"	—2250	·04
14	"	—3150	·26
15	"	0	·10
16	"	3150	—·47
17	"	0	—·01
18	"	4500	—1·31

Fig. 1.



ANNEALED CIRCULAR GLASS ROD.

Abscissas represent twisting moment per centimeter of length.
Ordinates represent rotation of the plane of polarization per centimeter of length.

Numbers without the negative sign are always positive. The positive direction of twist and rotation is taken throughout this paper as the direction which appears counter-clockwise to one looking in the direction of propagation of the ray of light.

TABLE II.

Experiment 14.

Twisting Moment per Centimeter = — 3150.

Azimuth.						Mean.
0	4·5	3·7	3·6	4·7	4·2	4·14
$\frac{\pi}{4}$	·7	1·8	3·	2·6	2·2	2·06
$\frac{\pi}{2}$	2·6	2·2	1·2	·7	·8	1·50
$\frac{3\pi}{4}$	7·2	8·0	7·6	8·2	8·7	7·94
π	—1·7	1·	—·7	—1·4	·3	—·48
$\frac{5\pi}{4}$	8·	8·6	8·7	8·7	8·8	8·56
$\frac{3\pi}{2}$	2·2	1·6	1 7	1·9	1·7	1·82
$\frac{7\pi}{4}$	—3·9	—4·8	—4·4	—3·6	—5·	—4·34

Mean =2·65

Experiment 16.

Twisting Moment per Centimeter = 3150.

Azimuth.						Mean.
0	·7	·8	1·1	—·1	1·	·74
$\frac{\pi}{4}$	—6·1	—5·1	—4·1	—4·7	—2·9	—4·58
$\frac{\pi}{2}$	—11·8	—10·4	—11·2	—10·8	—9·8	—10·80
$\frac{3\pi}{4}$	—11·7	—11·7	—11·3	—10·4	—9·8	—10·98
π	—·2	·8	—·9	—1·8	—2·3	—·88
$\frac{5\pi}{4}$	—9·6	—8·7	—8·	—7·	—5·3	—7·92
$\frac{3\pi}{2}$	—11·	—10·3	—8·8	—8·6	—7·6	—9·26
$\frac{7\pi}{4}$	—·8	—3·2	—2·1	—2·4	—1·8	—2·06

Mean = —5·72

These results, excepting those of the last experiment, are given graphically in Fig. 1. The results of the last experiment are uncertain since the cylinder broke after readings had been made in only two azimuths. The actual twist of the rod was always very small, not exceeding two degrees. The results indicate a rotation in the opposite direction to the twist which becomes very pronounced when the twist is large.

To illustrate these observations, the readings in experiments 14 and 16 are given in detail in Table II. The first column gives the azimuth, that is, the angle between the initial plane of polarization and an arbitrary radius of the glass cylinder; the last column the mean of the preceding five readings in units of the instrumental scale. The irregularity in the readings for a constant azimuth is due to the opacity and lack of homogeneity of the cylinder, which made the setting of the compensator somewhat rough, and the variation in different azimuths is due to double refraction. Although there are these large variations I think the final means have a qualitative value. The diameter of this glass cylinder was $7·55^{mm}$.

Glass is an unsatisfactory material for these experiments since it breaks easily and usually shows double refraction, so that observations are difficult. Agar agar, gum sandarach, gum Arabic, Burgundy pitch, borax glass and gelatine were carefully tried, but gelatine alone was found satisfactory.

Square glass plates were cemented to the ends of moderately heavy but soft rubber tubes a few centimeters long and 12^{mm} external diameter. Gelatine was reduced to a jelly by adding a suitable quantity of water, with gentle heat, and poured into these tubes through a slit in the side and allowed to cool. One of these square glass caps was placed in a square aperture at one end of a rigid frame. Over the other glass plate was slipped a circular wooden disk with an opening in the center slightly larger than the glass cap. The jelly tubes were twisted by turning this wooden disk in the frame. When the proper torsion had been secured the disk was clamped and the position of the analyzer read for sixteen different azimuths of the frame relative to the initial plane of polarization. The edge of the disk was graduated and enabled one to determine quite accurately the angle of torsion. The jelly was examined with a polarimeter, the polarizer of which was a reflecting surface of black glass and the analyzer a Nicol mounted on a graduated circle. A biquartz giving the sensitive tint was placed above the polarizing surface, and the substance to be examined between the biquartz and the Nicol. The jelly must be supported in flexible tubes of considerable stiffness. Independent cylinders of jelly were tried, and jelly in thin rubber tubes, but the weight of the jelly and its freedom of motion produced such double refraction that no observations were possible. The independent cylinders of jelly cracked under very slight torsion. Thin paper tubes were tried but found unsatisfactory.

In Table III are tabulated all the observations with jelly tubes. Some tubes were found so double refracting or opaque that determinations were impossible, but the observations are recorded for every experiment where readings could be made. The first column gives the chronological number of the experiment, the second the number of the jelly tube, the third the length of the tube, the fourth the twist per centimeter of length. The fifth column gives the rotation of the plane of polarization per centimeter of length. The readings in brackets for the jelly in its initial condition, before any twist, give the natural negative rotation of the gelatine, if it is pure, or the resultant positive rotation if sugar has been added. This initial rotation has been subtracted from all the readings without brackets so that the unbracketed numbers give the rotation produced by the twist. Each number of the fifth column is the mean of readings in sixteen azimuths.

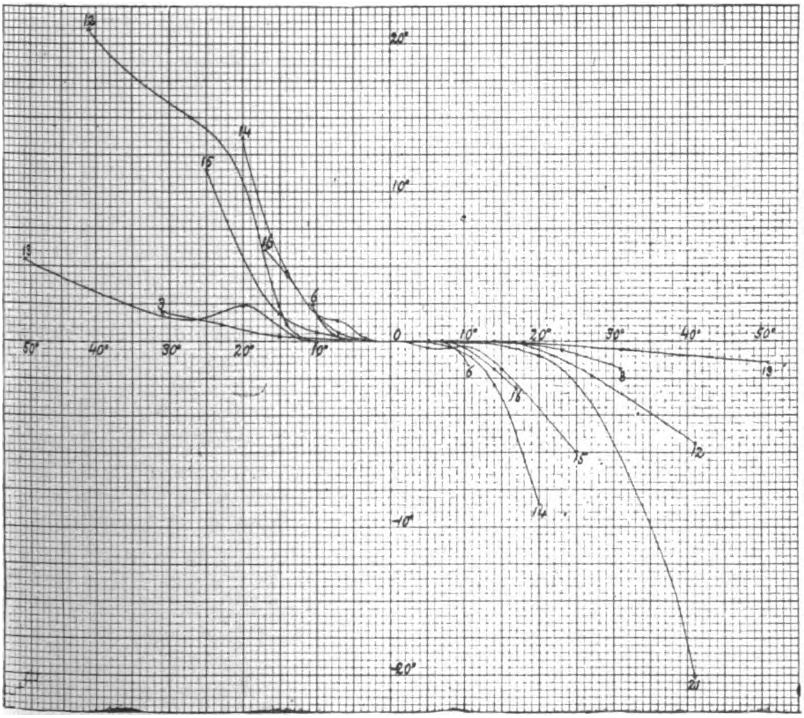
TABLE III.

I.	II.	III.	IV.	V.
1	1	5·5	15	(0°·63)
2	“	“	0	(·4)
3	“	“	−15	(·72)
4	“	“	0	(·65)
5	“	“	0	(·83)
6	“	“	15	(1·15)
7	2	“	23	(−3·3)
8	“	“	−23	(3·8)
9	3	“	−18	(2·0)
10	“	“	0	(1·7)
11	“	“	18	(·88)
12	“	“	−18	(·83)
13	“	“	0	(·5)
14	“	“	18	(−·27)
15	4	“	7	(1·15)
16	“	“	0	(1·08)
17	“	“	−9	(1·06)
18	3	“	0	(·32)
19	“	“	−7·6	·13
20	“	“	−15	·22
21	“	“	−23	1·1
22	“	“	0	·14
23	“	“	7·6	−·01
24	“	“	15	−·01
25	“	“	23	−·65
26	“	“	31	−1·84
27	“	“	−31	1·98
28	“	“	0	·2
29	“	“	0	·02
30	5	6	0	(·56)
31	“	“	7·6	− 5
32	6	4	0	(−1·2)
33	“	“	5·2	·1
34	“	“	10·5	−1·7
35	“	“	0	−·12
36	“	“	−5·2	·01
37	“	“	−10·5	2·4
38	7	1·55	0	(−1°·86)
39	“	“	27	−1·7
40	“	“	−27	16·7
41	8	2·07	0	(−1·8)
42	“	“	20	−·96
43	“	“	−20	·1
44	9	3·1	0	(−1·6)
45	“	“	14	−5·1
46	“	“	−14	·06
47	10	4·13	0	(−1·3)
48	“	“	10	2·5
49	“	“	−10	5·1
50	11	6·2	0	(−1·9)
51	“	“	6	3·7
52	“	“	−6	1·8
53	12	1·55	0	(−1·02)
54	“	“	14	−·03
55	“	“	−14	1·28
56	“	“	−27	15
57	“	“	27	−2·3
58	“	“	41	−6·9
59	“	“	−41	21
60	“	“	−41	17·6
61	13	2·07	0	(−·87)
62	“	“	10	−·12
63	“	“	−10	−·05
64	“	“	−20	2·04
65	“	“	20	−·18
66	“	“	31	−·54
67	“	“	−31	1·81
68	“	“	−51	5·49
69	“	“	51	−1·47
70	14	3·1	0	(−1·18)
71	“	“	7	−·23
72	“	“	−7	·56
73	“	“	−14	4·67
74	“	“	14	−2·98

I	II.	III.	IV.	V.
75	14	3·1	20	−10°·9
76	"	"	−20	13·7
77	"	"	−20	12·8
78	15	4·13	0	(−·96)
79	"	"	5	−·45
80	"	"	−5	·18
81	"	"	−10	·73
82	"	"	10	−·36
83	"	"	15	−1·94
84	"	"	0	·01
85	"	"	−15	1·8
86	"	"	0	−·25
87	"	"	25	−7·75
88	"	"	0	−·53
89	"	"	−25	11·5
90	"	"	−25	11·2
91	"	"	0	−·43
92	"	"	25	−10·8
93	"	"	25	−10·1
94	"	"	0	−·77
95	16	6·2	0	(−1·06)
96	"	"	3·4	−·02
97	"	"	−3·4	·23
98	"	"	−7	1·46
99	"	"	7	−·01
100	"	"	10	−·41
101	"	"	−10	1·78
102	16	6·2	−14	4°·38
103	"	"	14	−1·97
104	"	"	17	−3·17
105	"	"	−17	6·06
106	17	2·07	0	(−1·7)
107	"	"	−20	1·2
108	"	"	20	−1·4
109	"	"	51	−3·9
110	"	"	0	·3
111	18	"	0	(−·4)
112	"	"	+	·2
113	"	"	0	·24
114	19	3·1	20	(−1·8)
115	"	"	−20	(1·7)
116	"	"	0	(·34)
117	20	2·07	0	(−·78)
118	"	"	20	−4·37
119	"	"	−20	1·15
120	21	"	0	(−1·36)
121	"	"	20	−·98
122	"	"	41	−20·6
123	22	"	0	(−1·6)
124	"	"	20	−9·79
125	23	3·1	0	(−·71)
126	"	"	21	−5·63
127	"	"	21	−4·99
128	"	"	0	−·03

Tubes 1, 2, 3, and 5 were filled with a commercial prepared calves-foot jelly, flavored and sweetened. The jelly in tube 1 was too liquid, and the changes in the position of the analyzer are due to temperature changes and other disturbances. A small bubble of air was present in tube 2. The rubber tube of experiment 5 was 3^{cm} in diameter. It gave way after the first twist. Tubes 4, 6–16, 18–23, contained a jelly made from specially refined calves-foot gelatine. The jelly did not cling to the rubber tube or glass plates of tube 4. Tube 6 had a ring of blotting paper around the inside of each end to secure better adhesion. The observations of experiments 37–46 were somewhat uncertain on account of double refraction. The readings with tubes 10 and 11 are unreliable. In successive azimuths the position of the analyzer might change from +50° to −50° owing to great double refraction. Tubes 6–11, 20–23, were filled with very stiff jelly. In tube 18 the jelly was so liquid that it did not cling to the rubber walls or glass and consequently no careful reading of the torsion was made. Tube 17 contained very stiff French fish gelatine. After the experiments with this tube it was found that the polarimeter had been disturbed and that the analyzer and polarizer were parallel when the analyzer was at 11°·7. This probably occurred after the zero reading and this is assumed in the fifth column, but on account of this uncertainty this tube does not appear in the plot given later. Tubes 2, 3, 5–9, 12–17, 19–23 show clearly rotatory polarization in the opposite direction to the twist. The observations with tubes 3, 5, 6 (except the last experiment), 12–16, 19–23, are entitled to the greater confidence. As is remarked above, there is some uncertainty about the readings with tubes 2, 7–9, 17 and the last observations with 6. Tubes 1, 4, 10, 11, 18 do not show rotatory polarization in the opposite direction to the twist, but these observations were marked at the time they were made as very uncertain. The observations with the tubes for which the results have no uncertainty, and with which readings were made with more than one positive or negative twist, are represented graphically in fig. 2. It was interesting to notice that the jelly behaved as an elastic solid and did not flow with time as a semi-fluid. The rotation only slightly decreased when a severe twist was continued for hours, and when the twist was removed it nearly returned to its

Fig. 2.

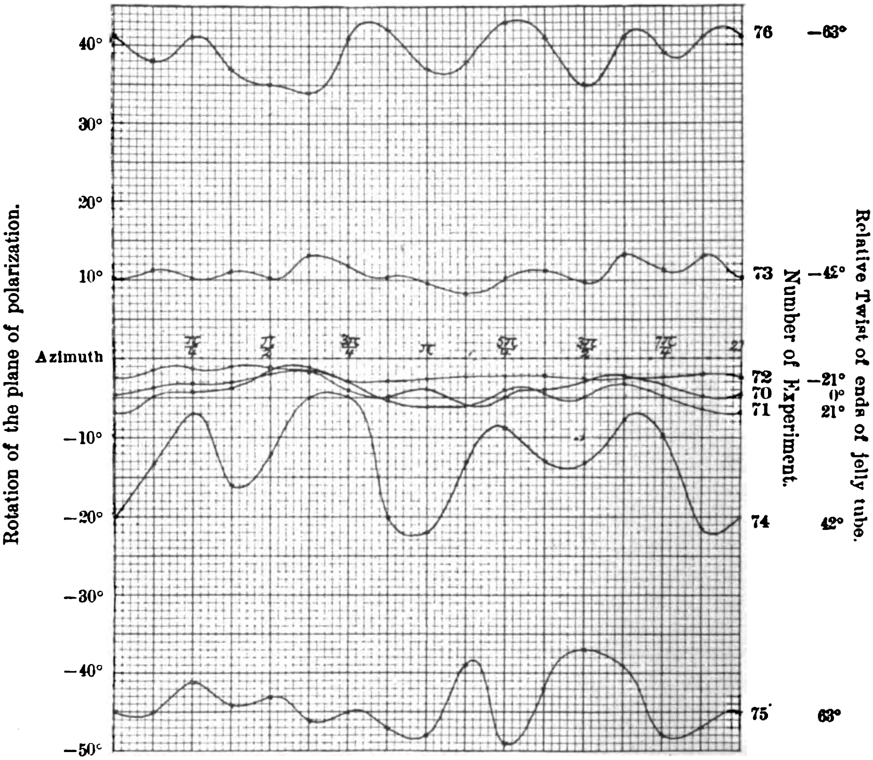


CALVES-FOOT JELLY IN RUBBER TUBES

Abscissas represent twist per centimeter of length.
Ordinates represent rotation of the plane of polarization per centimeter of length.
Numbers signify number of jelly tube.

original natural rotation. Experiments 28, 29, 35, 88, 91, 94, 128 show a small residual rotation after a large twist, but experiments 84 and 86 do not. Observation 60 was made 15 minutes after observation 59; 77, 2¾ hours after 76; 90, 2¾ hours after 89; 93, 48 hours after 92; 127, 2¾ hours after 126; the torsion having been kept constant during these intervals. These show a slight decrease in the rotation if the twist is continued for some time.

Fig. 3.



EXPERIMENTS WITH JELLY TUBE NO. 14.

TABLE IV.

Azimuths.

Twist.	Number of Experiment.	0	$\frac{\pi}{8}$	$\frac{\pi}{4}$	$\frac{3\pi}{8}$	$\frac{\pi}{2}$	$\frac{5\pi}{8}$	$\frac{3\pi}{4}$	$\frac{7\pi}{8}$	π	$\frac{9\pi}{8}$	$\frac{5\pi}{4}$	$\frac{11\pi}{8}$	$\frac{3\pi}{2}$	$\frac{13\pi}{8}$	$\frac{7\pi}{4}$	$\frac{15\pi}{8}$	Mean
0°	70	−4·6	3·6	3·3	3·	1·9	1·8	4·1	4·8	3 9	5·9	4·8	3 9	3·	2·2	3·3	4·7	−3°·7
21	71	−6·8	4·7	4·3	3·6	1·3	1·1	2·9	5·2	6·1	6·	4·	4·6	4·9	3·2	4·9	6·3	−4·4
−21	72	−2 4	1·4	1·3	1·	1·2	1·6	2·8	2·8	2 6	2·3	2·3	2·3	1·7	1·4	2·2	1·9	−1·95
−42	73	10·2	11·3	10·3	11·	10·2	13·1	11·8	10·3	9·7	8·4	10·1	11·2	9·7	13·4	11·2	13·2	10·9
42	74	−20	13.2	6·9	16	12·2	4 9	4·9	20	21·8	13·1	8·7	13·	13·1	7·6	9 9	21·4	−13·
63	75	−45	45	41	44	43	46	45	47	48	39	49	42	37	39	48	47	−37·8
−63	76	41	38	41	37	35	34	41	42	37	38	43	41	35	41	39	41	39·

To illustrate the character of these observations the readings with tube 14 are given in detail in Table IV and graphically in fig. 3. The abscissas are azimuths, that is, the angle between the initial plane of polarization and an arbitrary radius of the jelly cylinder and the ordinates are rotations of the plane of polarization. The variation in different azimuths with these jelly tubes is very much less than with the glass cylinder.

The effect of torsion in directions perpendicular to the axis was studied in the glass bar made by Duboscq and in a jelly tube with glass windows on the sides. No effect was apparent if the glass bar was exactly perpendicular to the ray of light and with the jelly tube the double refraction was too great for satisfactory observations.

These experiments demonstrate that torsion produces rotatory polarization in the opposite direction to the twist. The curves of fig. 2 indicate that the rotation of the plane of polarization is a function of the twist of degree higher than the first.

It is difficult to find any satisfactory explanation for these phenomena. Crystalline plates helically arranged rotate the plane of polarization, but these phenomena do not seem analogous. In the jelly tubes there could not have been originally any uniform mechanical difference of structure in directions at right angles to the axis of the tube and no such difference could be produced by the torsion in the case of glass. Even if each cross section was analogous to a crystalline plate the helical change of position of the axes would be continuous and not by steps, as is required in Mallard's theory of this rotatory polarization.* Nor can the phenomena be explained on the basis of a structure of helical fibres, for we cannot imagine jelly possessing a fibrous structure, and if we could the twisted fibers would be straight and not helical in distances comparable with the wave-length of light.

Excessively large twists were used in the experiments with jelly. Wertheim demonstrated experimentally in the memoir already referred to, that under large torsion a cylinder is shortened, the contraction being proportional to the distance from the axis. This longitudinal pressure with the torsion stresses would give a component stress in normal sections, but it would seem as if the conditions would be the same for either clockwise or counter-clockwise circular vibrations in these normal sections.

This investigation substantiated the statements of Verdet and Wertheim that the difficulties encountered in the choice of a proper material for experiment are very great. In jelly supported in rubber tubes a satisfactory combination was found, and the observations with jelly, corroborated in the glass, demonstrate that torsion produces rotatory polarization, the rotation of the plane of polarization being opposite to the twist and a function of the twist of degree higher than the first.

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* Ann. des Mines, VII, xix, 1891.

In conclusion, I wish to express my thanks to Prof. Wright, who suggested the subject and the general method of the work, and who afforded me all possible facilities for conducting this investigation.

Sloane Physical Laboratory,
Yale University, June 22, 1899.

ART. IX.—*Lichenaria typa* W. & S.; by F. W. SARDESON.

THE purpose of this article is to redescribe an important Tabulate coral from the Ordovician fauna of Minnesota, which has been wrongly referred. It is one of the oldest known Tabulata and its remarkably simple structure may be primitive to that of many others. It should therefore be given consideration whenever the question of origin and affinities of such Tabulata as *Heliolites*, *Favosites*, *Syringopora*, *et al.*, is discussed,—a question upon which paleontologists seem to be not of one opinion. *Lichenaria* presents some special evidence touching the origin of mural pores as seen in many Tabulata, and some remarks on that subject will therefore be added to the description.

Lichenaria typa W. & S., with *Protaræa vetusta* H. and *Aulopora trentonensis* W. & S., occurs in the lower part of the Galena (Trenton) stage, i. e. at about the exact horizon of the Black River formation of New York. Its occurrence is therefore a little earlier than that of *Houghtonia* (*Columnopora*), *Heliolites* and other Ordovician Tabulata excepting some Monticuliporoidea, although it may be considered as essentially their contemporary. Further, *Lichenaria* approaches in structure nearest to *Columnopora* Nicholson as interpreted by me formerly,* but it is very different from *Houghtonia* Rominger, which Lindström has recently asserted to be identical with *Columnopora*† (*Calapœcia* Bill). In fact Rominger and also Nicholson having both said that the same were probably congeneric, while the descriptions of their species are very different, a mistake of some kind is evident, and it may be best eliminated by following the authority of Lindström, loc. cit. In that case, my interpretation of Nicholson's *Columnopora* is faulty also. If it were not so, however, *Lichenaria* would be very near if not congeneric with *Columnopora* as interpreted by me and ranged with *Michelinia*. It is therefore of interest to know that a species of nearly the same structure and geologic age as *Columnopora* Sardeson non Nicholson, the existence of which Lindström has inadvertently denied, does nevertheless exist.

Winchell and Schuchert, in describing *Lichenaria*, referred it to the family Astræidæ of the Madreporaria Aporosa, and their description is unfortunate throughout. The fossil may be recognized, however, from the illustrations, and also since part of the type specimens were received from me and returned with their identification, I can not be mistaken as to the species which they intended to describe. *Lichenaria* should be referred to the Alcyonaria, Tabulata, near *Michelinia.*

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* Tabulaten, Neues Jahrb. Beilageband, x, p. 295 (1896).

† Heliolitidæ, Kongl. Svenska Vetenskaps-Akad. Handlingar, vol. xxxii, p. 76. (1899).

Lichenaria typa Winchell and Schuchert.

L. typa W. and S., Final rep. Geol. Sur. Minn., vol. iii, p. 83, pl. G. figs. 10–13. (1895). *L. minor* Ulrich, op. cit., p. 84, fig. 5.

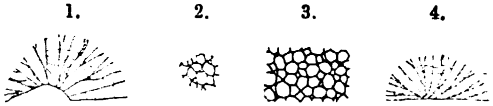

Fig. 1. Vertical section through a corallum, showing mural pores and tabulæ. The latter in part broken away. Fig. 2. Transverse section, showing mural pores, and one cœnenchymal cœcum. Fig. 3. Diagram of the surface of a typical specimen. Fig. 4. Ideal vertical section of specimen growing on plane surface.

Description. Corallum hemispheric or irregular, 20^{mm} or less in diameter, composed of polygonal cells and appearing like young *Favosites.* The corallum was always attached to a shell or a Monticuliporoid and often intergrown with the latter. The cells as a rule rapidly attain the size of 1 to 2^{mm} diameter. The largest cells are seen on largest or oldest colonies but graduation in size to the smallest young cells normally obtains and all colonies therefore appear immature. The cell walls are thin. The calycles are deeper than wide. New cells develop by intermural gemmation at the angles between four or three cells, or at the periphery of the colony intermediate to two older cells. The new cell is at first a round vertical (radial) pore, about $0{\cdot}2^{mm}$ in diameter, then as it enlarges it becomes finally polygonal from contact (fig. 3). When the growth is irregular from accidental cause, such as an intergrowing Monticuliporoid, some of the cells may be more or less Auloporoid in their development but there is no Aulopora stage normally. The colony evidently arises from a single polyp which builds a recumbent cell and which early buds off other polyps, resp. cells.

The cell margins are not notched, as now seen, except by the incipient mural pores. These furrows are found especially at the angles between cells, running diagonally between two or branching between three cells, and when they are about to be replaced by one or two incipient cells, small areas result such as Lindström might call cœnenchyma.* The corresponding mural pores are few and not in rows. They are easily found in transparent sections (fig. 1, 2). They are rather large and penetrate the face of the wall less often than the corners.

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* Lindström, op. cit., p. 10.

The vertical, intermural canals from which the new cells expand, arise from the mural pores or transverse canals, and hence they open at the bottom into two, rarely into three or one parent cell. But not all mural pores or canals give rise to vertical canals and young cells. In different specimens and different stages of the same, mural pores of both kinds are apparently proportionate to the number of incipient cells, although more numerous than these.

Tabulæ are few and thin, and like the walls they now present a fine crystalline structure only. There is no evidence of "baculi" such as compose the walls and tabulæ* of the well known *Protarœa.* Small direct mural spines, or pseudosepta, are sometimes present but are not distinguishably arranged in continuous rows.

Remarks. The presence of mural pores indicates relationship to such Tabulate corals as *Favosites* and especially to *Michelinia* and *Pleurodictyum*, but the transverse pores are less numerous than in these. The vertical pores or intermural canals are like those of *Pleurodictyum et al.*, and may be interpreted as siphonopores or as cœnenchymal cœca,† if indeed these be not homologous structures. From them budded the new polyp-cells. There are therefore three stages of structural development distinguishable, viz. *a* pore, i. e. transverse canal, *b* vertical canal, i. e. siphonopore or cœnenchymal cœcum, and *c* polyp-cell stage; but since in some cases a complete transverse canal is not developed, and in others such canals exist without accompanying second and third stages, it appears most probable that we have record of two distinct structures, viz., transverse canals and polyps, the young stage of the latter budding often but not always from the former.

It is noteworthy, however, that mural pores are most numerous where most new polyp cells are developing. Beecher's conclusion from study of *Pleurodictyum lenticulare* (Hall), "that primarily, the development of mural pores is identical or homologous with the process of gemmation,"‡ is supported, although insufficiently, by this last mentioned character of *Lichenaria.* If it could be assumed in the case of *Lichenaria*, that there were no transverse canals developed other than those which formed the mural pores, then *Lichenaria* would offer a little better evidence than *Pleurodictyum* in support of Beecher's view, since it might be said that non-productive mural pores were developing from productive ones because they are "developed when the period of gemmation is

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*Full grown, fairly well-preserved specimens of *Protarœa* do have tabulæ, Lindström, op. cit., p. 110, notwithstanding.

† Bourne. Philos. Trans, vol. clxxxvi, B. p. 455 (1895).

‡ Trans. Conn. Acad., vol. viii, p. 212 (1891).

in force," Beecher, op. cit. But it may be an open question whether in *Lichenaria* we see an early stage in the differentiation of transverse canals from stolons or whether it is the incipient stage of mural pore-building by the lodging of preexisting differentiated canals in the solid wall, as explained by Moseley's theory regarding *Favosites*. Very probably, however, Beecher's theory was suggested less from this kind of evidence, than from a supposed Aulopora stage in the development of *Pleurodictyum*, since if *Pleurodictyum* were derived from *Aulopora* then the stolonal structures of the latter would be the origin of those of the former which are also mural pores. But, Auloporoid growth in *Lichenaria* is not a normal one, as said, and it may be safely added that there is no Aulopora stage in the ontogeny of *Pleurodictyum lenticulare*, the figures 2, 3 and 4, pl. 9, op. cit., being palpably erroneous, and figures 9, 10 and 11 representing not a normal corallum.

Lichenaria appears to prove, therefore, that stolons and transverse canals and the consequent mural pores are older in origin than the oldest known Tabulata, and as to the evidence, it does not prove whether canals are older or younger than stolons, although the latter may be the case. The claim that *Aulopora* is ancestral to other Tabulata is not supported.

University of Minnesota, Minneapolis,
May 27, 1899.

ART. X. — *Studies in the Cyperaceæ;* by THEO. HOLM.

XI. On the abnormal development of some specimens of *Carex stipata* Muhl., caused by *Livia vernalis* Fitch. (With seven figures in the text drawn from nature by author.)

WHILE the *Cyperaceæ* have several enemies from among the parasitical fungi, they do not seem to be much troubled by parasitical animals. The effects of the attack in the first case prove seldom fatal to the host, since the leaves and leaf-sheaths become merely partially injured, and even if the fungus infests the utriculus of *Carex*, the result of which is generally the destruction of the enclosed caryopsis and seed, the host is, nevertheless, able to propagate itself by means of the rhizome. No outer signs of hypertrophy seem to develop from these diseases, since the tissues attacked by the fungus become rapidly destroyed, while the healthy parts of the leaves are still capable of performing their functions and retain their normal shape and size. It is different, however, when the roots become diseased from this cause, and although such cases seem to be exceedingly rare, we observed a few in *Cyperus flavescens* L., the roots of which were infested with *Schinzia cypericola* Magnus,* which were growing under perfectly normal conditions along the banks of a stream near Washington, D. C. The diseased roots had become very visibly hypertrophied, having increased considerably in thickness at the ends, thus forming small hand- or finger-shaped tumors. But otherwise we have, so far, never observed any such development of "gall" in *Cyperaceæ*, attacked by fungi. There are, however, some certain kinds of malformations, which have been recorded in a number of species of *Carex*, in which the female inflorescences show ramifications, due to a prolongation of rhacheola, but such cases are not to be considered as caused by parasites; they may, as suggested by Duval-Jouve,† be due to the conditions of the soil. Another case is where the utriculus of *Carex disticha* shows a marked increase in size, but this abnormal condition does not seem to have been proved as being caused by parasites. In *Heleocharis* and *Scirpus* there are several species which are frequently viviparous, evidently without being affected by any kind of actual disease; similar viviparous forms are, also, met with among the *Gramineæ*, where they are not uncommon, e. g., the variety "*vivipara*" of *Poa bulbosa*, *Aira alpina*, *Festuca ovina*, *Anthoxanthum odoratum*, etc.‡

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* The fungus was kindly identified by Professor Geo. F. Atkinson.

† Duval-Jouve: Sur la signification morphologique d'une anomalie que présentent les utricules de quelques carex. (Bull. soc. bot. de France, vol. xi, 1864.)

‡ The author: Notes on the flowers of *Anthoxanthum odoratum* L. (Proceed. U. S. National Museum, vol. xv, 1892, p. 399.)

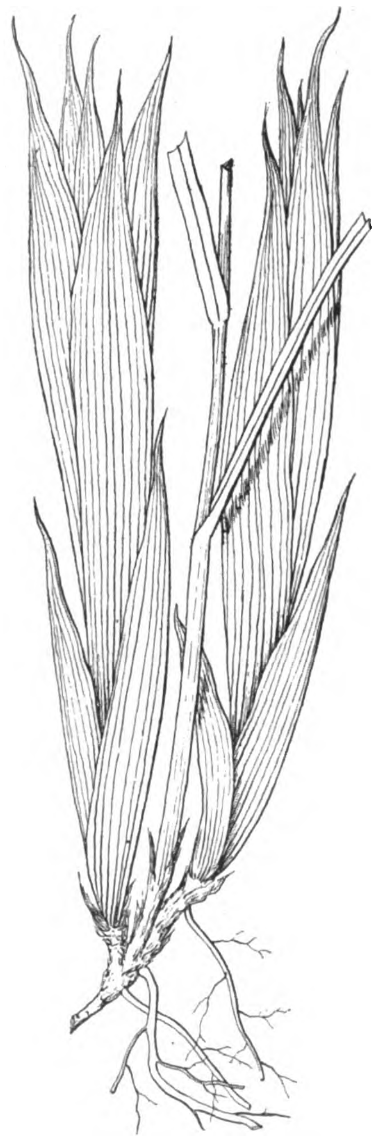

FIG. 1. *Carex stipata* Muhl. Diseased specimen, showing two leafy shoots with abnormally developed leaves and the base of a flower-bearing stem, which is not diseased; natural size.

But if we summarize the various causes of diseases and abnormal development as we know these in the *Cyperaceæ*, these do not seem to have been produced by animals, neither as ekto- or endo-parasites. It may, therefore, be of some interest to report an instance where a *Carex*, *C. stipata* Muhl., had become infested by *Livia vernalis* Fitch,* which had caused the foliar organs to develop very abnormally.† The specimens of this *Carex* we found growing under natural conditions, in damp places in woods near Surratsville, Pr. George County, Maryland. They attracted our attention by the unusual size of the leaves, which furthermore were pure white excepting at the tips, which were pale green. The specimens affected in this way were not, however, diseased throughout, as several normally developed shoots, floral and vegetative, were found on the same rhizomes that bore the hypertrophied. The accompanying illustration (fig. 1) shows a part of a diseased specimen with the base of a normal flower-bearing stem and two abnormally developed vegetative shoots. Besides having attained an unusual width and being almost destitute of chlorophyll, these hypertrophied leaves were furthermore flat along their entire length without the usual tubular sheath. The larvæ of the parasite were located on the upper surface of the leaves, but no punctures were visible, hence the eggs had simply been deposited upon the surface of the leaves, while these were very young and their tissues not quite differentiated.

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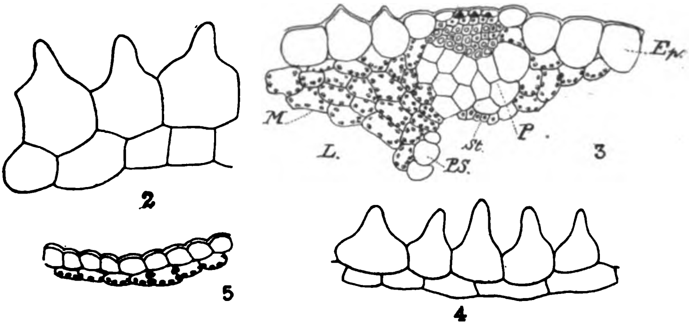
* The writer is indebted to Dr. Eug. A. Schwartz for the identification of *Livia*.

† Compare Buchenau Fr. Ueber Knollen- und Zwiebel-bildung bei den Juncaceen (Flora, 1891, p. 81).

In comparing the internal structure of a diseased leaf with a healthy one, the most notable difference seems to lie in the epidermis of both faces. This is affected to such an extent that the cells have not only become enlarged, but the outer wall of each individual cell forms a very distinct and projecting, conical papilla. In the healthy leaf the cells of epidermis are rather small on the lower surface with only a few short and wart-like protuberances along the margins of the leaf-blade. On the upper surface the epidermis consists of larger cells, especially above the mesophyll, and wart-like protuberances occur here and there near the ribs and along the margins. Bulliform-cells are developed as a large group above the midrib in both the healthy and diseased leaves, but in the latter these cells are very much larger and more numerous. Cells, containing silicious cones, occur as usual outside the hypodermal stereome in the normal leaves, but are almost wanting in those diseased; the same is the case, also, with the stomata, which were noticed only on the lower surface of the green apex, the other part of the blade being destitute of chlorophyll, as stated above. The mechanical tissue, the stereome, is rather thin-walled in the affected leaves, but forms here longer and



Transverse sections of diseased and healthy leaves of *C. stipata.*

FIG. 2. Epidermis and outer layer of mesophyll from the upper surface of diseased leaf.

FIG. 3. Epidermis (Ep.), mesophyll (M.), stereome (St.), colorless parenchyma (P), and parenchyma-sheath (P.S.) from upper face of healthy leaf.

FIG. 4. Epidermis and outer layer of mesophyll from the lower surface of diseased leaf.

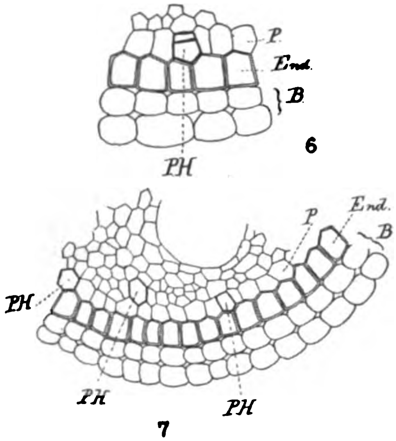
FIG. 5. Epidermis and mesophyll from the lower surface of healthy leaf. ×240.

narrower groups than in the healthy ones, when considered in transverse sections. The mesophyll consists of a homogeneous, colorless tissue in the diseased leaves and is traversed by lacunes of considerable width, while this same tissue, in the healthy leaf, is differentiated into a compact, chlorophyll-bearing tissue on the upper face and a more open pneumatical tissue below; lacunes are present, but they are relatively smaller. In considering the mestome-bundles, these show the same structure in both leaves, but are more numerous and much broader in those diseased; a parenchyma- and a mestome-sheath are present in both and show the same difference in size, as observed in the other tissues. A study of the silica-skeleton demonstrated the fact, that this matter was almost absent in the infested leaves in contrast to the others.

While our specimens thus possessed both normally and abnormally developed leaves, it seemed as if the rhizome had undergone some modification in its entire length. The bark-parenchyma appeared, however, to be perfectly healthy, representing an outer and inner zone having cells thick-walled and thin-walled respectively and filled with starch; there was, also, an endodermis with the inner walls somewhat thickened. By examining the interior part of the rhizome, the mestome-bundles, these were scattered in the thin-walled, starch-bearing fundamental tissue, and they represented as commonly noticed both collateral and perihadromatic bundles. Very noticeable were the narrow vessels, besides the very weakly developed stereome around each of the mestome-bundles. When compared with a rhizome of a healthy specimen, the difference was very striking and most pronounced by the narrow lumen of the various vessels.

Although the roots showed no signs of any abnormal development, we thought desirable to describe their structure, which exhibited some points that may be of interest for comparative studies of these organs. Their structure is as follows. Inside the epidermis are about four layers of thin walled, but persistent bark-parenchyma, which surrounds the inner bark, the cells of which show the usual tangential collapsing, excepting the two innermost strata. There is, besides, a typical endodermis, of which the cell-walls are slightly thickened all around. The pericambium is very thin-walled and demonstrates the fact (figs. 6 and 7) that it is not interrupted by all the proto-hadrome vessels. Out of thirteen of these vessels two were observed to lie within the pericambium, separated by this from endodermis. In some cases (fig. 6) there was not only one proto-hadrome vessel developed, but two, and contrary to the rule, as it appears, the inner was the smaller. The leptome showed no divergence from that of other roots and the innermost part of the central-cylinder was occupied by conjunctive tissue with four large vessels.

The approaching or non-approaching of the proto-hadrome to the endodermis has been very broadly discussed in Klinge's classical work, to which we have referred in several of our previously published articles. It appears, according to his observations, that the most common case in the *Cyperaceæ* is that the proto-hadrome borders immediately on the endodermis; this he observed in a number of European species of *Carex*, also in some species of *Eriophorum*, *Scirpus*, *Heleocharis* and of *Cyperus*, the last having previously been studied by Duval-Jouve. However in a few species of *Carex: hirta*, *rhyncophysa* and *hordeiformis* he observed the same peculiarity as we have described for *C. stipata*, that not all of the proto-hadrome vessels showed this position, but that some were located inside the pericambium. Furthermore, Klinge, Van Tieghem and Duval-Jouve discovered, that in certain species of *Cyperus* and *Galilea* from the old world none of the proto-hadrome vessels bordered on endodermis. In the North American *Cyperaceæ*, which we have studied so far, we have constantly observed the proto-hadrome to be in contact with endodermis, the only exception being *Carex Fraseri*, *Fimbristylis castanea*, and this particular case, described above, in *Carex stipata*. This is the more interesting since it seems, also, to be a very rare case in the old world species of *Carex*. It is stated by Van Tieghem as characteristic of *C. brizoides*,



FIGS. 6 and 7. Transverse section of root of *Carex stipata*. B = bark-parenchyma; End. = endodermis; PH = proto-hadrome; P = pericambium. x 560 and x 400.

to which Mazel* has later on added: *Carex arenaria*, *C. humilis*, *C. depauperata*, *C. glauca*, *C. alba* and *C. alpestris*. This irregular position of the proto-hadrome in our specimens of *C. stipata* does not, therefore, seem to be in any way the result of disease, since it has, also, been observed in other species with no symptoms of anomaly.

While the disease in *Carex stipata* had not caused the development of a gall or gall-like formation, it is, nevertheless, to be recorded, that there is one analogy to be found in respect to the manner in which the epidermis has been modified in its structure. Küstenmacher† in his interesting work upon galls, describes the various modifications that are observable in the tissues which compose the gall; among these is the so-called nutritive-layer (Nährschicht) which surrounds the animal-embryo, and of which the inner epidermis develops into a mass of papillæ ("papillöse Nährhaare"). As we have stated above, the leaf-surface of our *Carex* showed a corresponding structure with a dense covering of papillæ, but it is, however, far from certain that their function was the same. It seems more probable that the excessive but sickly development of all the parts of the leaf was produced by a kind of irritation, caused by the depositing of the eggs upon the young leaf-surface, without the abnormal structure being of any advantage to the parasite. And although the parasitism was purely superficial from its beginning to end, it, nevertheless, resulted in such important physiological disturbances as: the almost complete non-development of stomata, chlorophyll, lignin and the partial non-absorption of silica.

Brookland, D. C., February, 1899.

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* Mazel, Antoine: Etudes d'anatomie comparée sur les organes de végétation dans le genre Carex. Thèse. Genève, 1891, p. 88.

† Küstenmacher, Max: Beiträge zur Kenntniss der Gallenbildungen mit Berücksichtigung des Gerbstoffes. (Pringsheim's Jahrb. f. wiss. Botanik, vol. xxvi, Heft I. Berlin, 1894, Inaug. diss.)

ART. XI. — *The Constitution of Tourmaline*; by F. W. CLARKE.

SOME years ago, in an extended paper upon the constitution of the silicates,* I proposed a formula for tourmaline which seemed to satisfy all known conditions. Recently, in the February number of this Journal, Penfield and Foote† have offered still another interpretation of the analyses, and support their views with a considerable weight of argument. The appearance of their paper has led me to rescrutinize the evidence more in detail than previously; and the result has been to modify my formulæ in some particulars, while retaining them in their general form.

According to Penfield and Foote all tourmaline may be represented as salts of the alumino-borosilicic acid $H_{11}Al_3B_2Si_4O_{21}$, in which two hydroxyls are permanently linked to boron, leaving an available valency or basicity of nine. In my formulæ all tourmalines are derived from the similar acid $H_{14}Al_5B_3Si_6O_{31}$, with all of the hydrogen atoms replaceable by bases. Upon bringing the two acids to the common basis of six silicon atoms, they compare as follows:

Penfield and Foote	$H_{16\frac{1}{2}}Al_{4\frac{1}{2}}B_3Si_6O_{31\frac{1}{2}}$
Clarke	$H_{14}Al_5B_3Si_6O_{31}$

Replacing aluminum by hydrogen in order to show the ultimate acids, these expressions become

Penfield and Foote	$H_{30}B_3Si_6O_{31\frac{1}{2}}$
Clarke	$H_{29}B_3Si_6O_{31}$

The small difference between the empirical formulæ is thus made evident, and it hardly amounts to more than the uncertainties in the analyses. In fact, the trustworthy analyses of tourmaline give ratios lying between and beyond both extremes, as the following formulæ, computed from Riggs' data, show: In these expressions fluorine has been assumed equivalent to hydroxyl.

Pierrepont, black	$H_{28\cdot87}B_{2\cdot93}Si_6O_{30\cdot83}$
Paris, "	$H_{30\cdot73}B_{2\cdot66}Si_6O_{31\cdot35}$
Stony Point, "	$H_{30\cdot23}B_{3\cdot02}Si_6O_{31\cdot65}$
Auburn, colorless	$H_{29\cdot25}B_{2\cdot77}Si_6O_{30\cdot78}$
Brazil, red	$H_{30\cdot79}B_{2\cdot78}Si_6O_{31\cdot56}$
Gouverneur, brown	$H_{28\cdot36}B_{2\cdot95}Si_6O_{30\cdot61}$
Hamburgh, "	$H_{30\cdot93}B_{3\cdot05}Si_6O_{32\cdot14}$

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* Bulletin U. S. Geological Survey, No. 125, 1895.

† This Journal, vol. vii, p. 97, 1899.

The two analyses by Penfield and Foote, however, conform sharply to their formula, thus:

De Kalb, white	$H_{29\cdot86}B_{3\cdot03}Si_6O_{31\cdot48}$
Haddam Neck, green	$H_{29\cdot98}B_{3\cdot06}Si_6O_{31\cdot59}$

The Gouverneur and Hamburgh tourmalines represent the extreme range of variation; a variation which is too large to be safely set aside as due to analytical errors or to impurities in the material analyzed. Some of the formulæ approximate to mine, some to that of Penfield and Foote, and hence it seems probable that neither formula, without some qualification, can safely be taken as final.

In order to be satisfactory, a constitutional formula must fulfil several conditions. First, it must adequately express the composition of the compound in question, covering all of its variations. Secondly, it must be readily applicable to the full discussion of analyses, so that the different isomorphous salts which are commingled in a mineral species can be separately identified and given reasonable expressions. Finally, it should indicate the relations between a species and the other minerals with which it is allied, or into which it commonly alters. A formula can be fully adopted only when all of these conditions are satisfied. The third condition, which relates to function, is equally important with the other two.

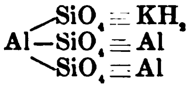
With the tourmalines, the micas seem to be most nearly akin. In each group we have to consider comminglings of isomorphous molecules, and when tourmaline alters, a mica is commonly the product of the reaction. In composition, also, the two groups show an apparent parallelism. With the lithia mica, lepidolite, lithia tourmalines occur; with muscovite and biotite, the common iron tourmaline is associated; and the magnesian tourmalines, which show the minimum of alumina in their composition, are similarly allied to phlogopite. This relationship, if it is real, should be suggested in the formulæ assigned to the several species.

To the commoner micas a simple series of formulæ can be easily given, thus:

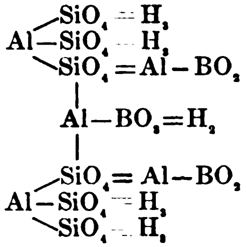
Muscovite	$Al_3(SiO_4)_3KH_2$,
Biotite	$Al_2(SiO_4)_3Mg_2KH$,
Phlogopite	$Al_1(SiO_4)_3Mg_3KH_2$;

and to these types or mixtures of them, most micas are referrable. The variations and exceptions have been considered elsewhere, and need not be discussed here.

With these fundamental molecules the corresponding salts of the tourmaline acid $H_{29}B_3Si_6O_{31}$, or $H_{14}Al_5B_3Si_6O_{31}$ are structurally correlated. The subjoined formulæ are sufficient to make this point clear; and to render the splitting up of tourmaline, its alteration into mica, somewhat intelligible.



Muscovite



The Tourmaline Acid.

In the acid, two hydrogen atoms are united with the orthoboric group, and twelve with the orthosilicate portion of the nucleus. Hence, to avoid repetition of the structural expression, the formula may be condensed into a linear form as follows:

$$Al_5(SiO_4)_6(BO_2)_2 \,.\, BO_3H_2 \,.\, H_{12},$$

and this is applicable to the discussion of the analyses. For example, Riggs' analysis of the black magnesium tourmaline from Pierrepont, N. Y., corresponds to the following molecular mixture:

13. $Al_5(SiO_4)_6(BO_2)_2 \,.\, BO_3Ca \,.\, Mg_4H_4$
7. $Al_5(SiO_4)_6(BO_2)_2 \,.\, BO_3Mg \,.\, Mg_4H_4$
2. $Al_5(SiO_4)_6(BO_2)_2 \,.\, BO_3Na_2 \,.\, Al_2Na_4H_2$

Comparing this with the analysis, and reducing the latter by union of like bases and recalculation to 100 per cent, we have—

	Found.	Reduced.	Calculated.
SiO_2	35·61	37·19	37·05
B_2O_3	10·15	10·51	10·80
Al_2O_3	25·29	27·10	27·19
Fe_2O_3	·44		
TiO_2	·55		
CaO	3·31	3·45	3·40
FeO	8·19	16·31	16·28
MgO	11·07		
Na_2O	1·51	1·72	1·74
K_2O	·20		
H_2O	3·34	3·72	3·54
F	·27		
	99·93	100·00	100·00

The result is evidently satisfactory. In dealing with titanium I have followed Penfield, regarding it as really Ti_2O_3 and equivalent to alumina. The fluorine is treated as replacing hydroxyl and is, therefore, united with the water. It is possible, however, that fluorine may sometimes replace the group BO_3, an equivalency which is strongly indicated in the cappelenite group of minerals.

The brown tourmaline from Gouverneur, N. Y., as analyzed by Riggs, also reduces to a similar mixture of molecules, and its composition may be written thus:

5. $Al_6(SiO_4)_6(BO_2)_2 . BO_3Ca . Mg_4H_4$,
3. $Al_6(SiO_4)_6(BO_2)_2 . BO_3Mg . Mg_4H_4$,
2. $Al_6(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_2Na_2H_4$;

and the comparison between analysis and theory is as follows:

	Found.	Reduced.	Calculated.
SiO_2	37·39	37·54	37·32
B_2O_3	10·73	10·76	10·88
Al_2O_3	27·79	28·72	28·53
Fe_2O_3	·10		
TiO_2	1·19		
FeO	·64	14·51	14·52
MgO	14·09		
CaO	2·78	2·79	2·90
Na_2O	1·72	1·83	1·93
K_2O	·16		
H_2O	3·83	3·85	3·92
	100·42	100·00	100·00

By consolidating lime with magnesia the expressions for both tourmalines might be simplified; but in other cases this would not be warranted. In some tourmalines calcium seems rather to replace sodium, or else the group NaH; a probability which will appear later.

In these two tourmalines the theoretical silicon-oxygen ratio Si_6O_{31} is assumed, in accordance with my original formula. We may now consider the cases in which that ratio is exceeded, with more or less approach to the formula proposed by Penfield and Foote. This condition is easily satisfied by regarding one of the component salts of tourmaline as slightly basic; containing the bivalent group $=Al-O-H$ or $=Al-F$ as an essential factor. With this assumption, which recognizes the equivalency of hydroxyl and fluorine, the analyses reduce to the general type indicated in the two preceding examples. For instance, the white tourmaline from DeKalb, N. Y., has the following composition:

10. $Al_5(SiO_4)_6(BO_2)_2 . BO_3(AlOH) . Mg_4H_4$.
20. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Ca . Mg_4H_4$.
3. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Na_2 . Al_3Na_3$.

For comparison the analyses by Penfield and Foote and by Riggs are available. In this case the minute quantities of titanium are ignored.

	Found.		Reduced.			
	P. & F.	Riggs.	P. & F.	Riggs.	Mean.	Calculated.
SiO_2	36·72	36·88	36·56	36·81	36·69	36·79
TiO_2	·05	·12	....	....	....	....
B_2O_3	10·81	10·58	10·76	10·56	10·66	10·74
Al_2O_3	29·68	28·87	29·55	28·81	29·18	29·07
FeO	·22	·52				
MgO	14·92	14·53	14·97	14·79	14·88	14·86
CaO	3·49	3·70	3·47	3·69	3·58	3·48
Na_2O	1·26	1·39	1·28	1·50	1·39	1·44
K_2O	·05	·18				
H_2O	2·98	3·56	3·41	3·84	3·62	3·62
F..........	·93	·50				
	101.11	100·83	100·00	100·00	100·00	100·00

The dark brown tourmalines from Orford, N. H., and Monroe, Conn., as analyzed by Riggs, also reduce to similar form, and approximate to the mixture

15. $Al_5(SiO_4)_6(BO_2)_2 . BO_3(AlOH) . Mg_4H_4$,
6. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Ca . Mg_4H_4$,
8. $Al_5(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3Na_2H$,

with the comparison as follows:

	Found.		Reduced.		
	Orford.	Monroe.	Orford.	Monroe.	Calculated.
SiO_2	36·66	36·41	36·96	37·34	36·84
B_2O_3......	10·07	9·65	10·16	9·89	10·74
Al_2O_3	32·84	31·27	33·28	33·13	33·11
TiO_2......	·23	1·61			
FeO	2·50	3·80			
MgO	10·35	9·47	11·84	11·88	11·85
CaO......	1·35	·98	1·36	1·00	1·19
Na_2O	2·42	2·68	2·58	2·88	2·62
K_2O......	·22	·21			
H_2O	3·78	3·79	3·82	3·88	3·65
	100·42	99·87	100·00	100·00	100·00

Here the divergence between the composition as found and as calculated is evidently due to the low determinations of boric acid in the analyses. Still, the comparison is close.

Between the magnesium tourmalines and the iron tourmalines the closest analogy exists, and the identity of type is absolute. Taking, except when otherwise specified, the analyses by Riggs, all the iron tourmalines reduce to mixtures of the following isomorphous molecules:

$$\left.\begin{array}{ll} \text{A.} & Al_6(SiO_4)_6(BO_2)_2 . BO_3(AlOH) . Fe_4H_4, \\ \text{B.} & Al_6(SiO_4)_6(BO_2)_2 . BO_3Ca . Fe_4H_4, \end{array}\right\}$$

$$\left.\begin{array}{ll} \text{C.} & Al_6(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3NaH_2, \\ \text{D.} & Al_6(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3Na_2H, \\ \text{E.} & Al_6(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3Na_3. \end{array}\right\}$$

Molecules C, D, and E are evidently identical, except in the varying replacements of sodium by hydrogen. A and B are similarly alike, so that actually only two fundamental compounds are assumed. From the commoner iron tourmalines lime is practically, if not quite absent; and these may be interpreted very nearly as mixtures of A and C, such as A_8C_5, A_7C_5, etc. If we take the minute quantities of lime into account, the black tourmalines from Brazil and from Stony Point, N. C., correspond to $A_{18}B_2C_9$; that from Auburn, Me., to $A_{35}B_2C_{27}$; and that from Paris, Me., to $A_{10}B_1C_9$. It will be noticed that the molecule A is in excess of the other two; a condition which fits the analyses, but which is incompatible with the formula proposed by Penfield and Foote. To satisfy the latter the number of A molecules should be exactly equal to B+C, giving the ratio Si_4O_{21} or $Si_6O_{31\frac{1}{2}}$. The analyses in question are as follows:

	Brazil.	Stony Point.	Auburn.	Paris.
SiO_2	34·63	35·56	34·99	35·03
B_2O_3	9·63	10·40	9·63	9·02
TiO_2	....	·55	....	....
Al_2O_3	32·70	33·38	33·96	34·44
Fe_2O_3	·31	....	....	1·13
FeO	13·69	8·49	14·23	12·10
MnO	·12	·04	·06	·08
MgO	2·13	5·44	1·01	1·81
CaO	·33	·53	·15	·24
Li_2O	·08	trace	....	·07
Na_2O	2·11	2·16	2·01	2·03
K_2O	·24	·24	·34	·25
H_2O	3·49	3·63	3·62	3·69
F	·06	....	....	....
	99·52	100·42	100·00	99·89

The reduced analyses and their comparison with the calculated composition is as follows:

	Found. Stony Pt.	Found. Brazil.	Calc. $A_{13}B_2C_9$.	Found. Auburn.	Calc. $A_{25}B_2C_{27}$.	Found. Paris.	Calc. $A_{10}B_1C_9$.
SiO_2 ...	34·10	34·26	34·27	34·75	34·48	34·70	34·62
B_2O_3 ...	9·98	9·54	9·99	9·56	10·06	8·94	10·10
Al_2O_3 ..	32·37	32·54	32·36	33·73	33·28	34·82	33·60
FeO ...	17·33	17·45	17·14	15·99	15·95	15·30	15·23
CaO ...	·52	·33	·45	·15	·17	·25	·27
Na_2O ..	2·22	2·40	2·22	2·23	2·50	2·33	2·67
H_2O ...	3·48	3·48	3·57	3·59	3·56	3·66	3·51
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Here again the agreements between analysis and theory are as close as could be reasonably expected. The same thing is true of the black tourmalines from Haddam, Conn., and Nantic Gulf. Using letters to represent the several molecules, as above, the Haddam mineral is sharply represented by $A_4B_1D_2$, and that from Nantic Gulf by $A_6B_7C_3E_1$. Here is the comparison:

	Haddam.			Nantic Gulf.		
	Found.	Reduced.	Calc.	Found.	Reduced.	Calc.
SiO_2	34·95	33·78	33·67	35·34	33·34	33·60
B_2O_3	9·92	9·60	9·82	10·45	9·86	9·80
TiO_2	·57	30·74	30·67	·40	29·01	28·84
Al_2O_3	31·11			30·49		
Fe_2O_3	·50			....		
FeO	11·87	19·31	19·24	8·22	20·46	20·55
MnO	·09			trace		
MgO	4·45			7·76		
CaO	·81	·78	·75	2·32	2·19	2·15
Na_2O	2·22	2·30	2·48	1·76	1·74	1·70
K_2O	·24			·15		
H_2O	3·62	3·49	3·37	3·60	3·40	3·36
	100·35	100·00	100·00	100·49	100·00	100·00

To the lithia tourmalines, as analyzed by Riggs, a similar set of formulæ apply, although the comparison between fact and theory is not quite so close as in the preceding cases. The red tourmalines from Brazil and from Rumford, Maine, are very nearly represented by the expression

$$Al_6(SiO_4)_6(BO_3)_2 . BO_3R'H . Al_3R'H_2 ;$$

with Li : Na approximately as 5 : 4. The slight deficiency in the alkalies is made up by the presence of small amounts of calcium, iron and manganese; but the ratio $Al_8 : Si_6$ is very clear. The green tourmalines are all lower in alumina, and range downward towards the iron end of the series; and like the latter are representable as mixtures of the following molecular types:

A. $Al_5(SiO_4)_6(BO_2)_2 . BO_3(AlOH) . Fe_4H_4$.
B. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Ca . Fe_4H_4$.
C. $Al_5(SiO_4)_6(BO_2)_2 . BO_3LiH . Al_2Li_2H_4$.
D. $Al_5(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3NaH_2$.
E. $Al_5(SiO_4)_6(BO_2)_2 . BO_3H_2 . Al_3NaH_2$.

Thus the dark, opaque green tourmaline from Rumford, Me., is a molecular mixture corresponding to $A_6B_2C_7D_{14}$;E_5; the similar mineral from Auburn is $A_8B_1C_8D_{17}$; the light green from Auburn, $A_2B_3C_{10}D_8E_{12}$; and the nearly colorless from Auburn, $A_1B_5C_{20}D_{10}E_{35}$. From Brazil, the dark green is $A_2B_1C_6D_8$, and the light green is $A_1B_2C_9D_8E_5$. The complexity of these expressions is only apparent, not real; as a study of the original type formulæ will show. They compare with the *reduced* analyses as follows:

	Rumford.		Auburn, dark.		Auburn, medium.		Auburn, pale.	
	Found.	Calc.	Found.	Calc.	Found.	Calc.	Found.	Calc.
SiO_2 ..	36·68	36·69	36·37	36·45	37·95	37·52	38·25	37·92
B_2O_3 ..	10·26	10·69	9·98	10·63	10·57	10·94	10·30	11·05
Al_2O_3 .	38·26	37·74	36·89	37·21	38·11	39·02	39·92	40·17
FeO ..	6·78	6·90	7·94	7·72	4·47	4·28	2·75	2·56
CaO ..	·34	·34	·17	·16	·50	·50	·43	·49
Na_2O .	3·12	3·07	3·19	3·14	2·58	2·58	2·55	2·53
Li_2O ..	·95	·94	1·06	1·07	1·35	1·35	1·34	1·34
H_2O ..	3·61	3·63	4·40	3·62	4·47	3·81	4·46	3·94
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

	Brazil, dark.		Brazil, light.	
	Found.	Calc.	Found.	Calc.
SiO_2..........	37·24	37·14	37·49	37·64
B_2O_3	9·95	10·83	10·32	10·97
Al_2O_3	38·66	38·07	39·86	39·04
FeO..........	5·49	5·24	3·74	3·61
CaO	·39	·35	·49	·46
Na_2O.........	2·90	3·01	2·59	2·76
Li_2O	1 63	1·64	1·71	1·69
H_2O..........	3 74	3·72	3·80	3·83
	100·00	100·00	100·00	100·00

In these cases the low boric acid of the analyses, and the uncertainties as to the significance of the water determinations, account for the chief variations between observation and theory. There is another complication also, due to the fact that alternative expressions are possible, between which it is very difficult to decide. In the tourmaline from Haddam Neck, Conn., analyzed by Penfield and Foote, a somewhat different commingling of molecules seems to be necessary, partly on account of the higher proportion of lime in the mineral, and partly on account of the fluorine. This tourmaline, also, admits of various alternatives in formulation; but it agrees well with the molecular mixture

3. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Ca . Fe_4H_4$,
10. $Al_5(SiO_4)_6(BO_2)_2 . BO_3(AlOH) . Al_2Li_2H_4$,
1. $Al_5(SiO_4)_6(BO_2)_2 . BO_3Ca . Al_3NaH_2$,
6. $Al_5(SiO_4)_6(BO_2)_2 . BO_3NaH . Al_3NaH_2$;

in which Ca is equivalent to a replacement of NaH. This mixture, with the group AlOH proportional to fluorine, gives a good comparison between analysis and theory, thus:

	Found.	Reduced.	Calculated.
SiO_2	36·96	36·75	36·86
B_2O_3	11·00	10·94	10·74
TiO_2	·03		
Al_2O_3	39·56	39·35	39·44
FeO	2·14	4·35	4·43
MnO	2·00		
MgO	·15		
CaO	1·28	1·27	1·15
Na_2O	2·10	2·09	2·07
Li_2O	1·64	1·63	1·54
H_2O	3·10	3·62	3·77
F	1·13		
	101·09	100·00	100·00

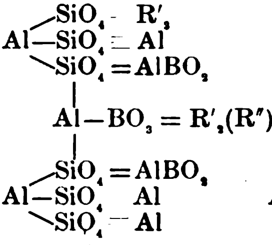
The theoretical amount of fluorine needed to replace hydroxyl in the assumed group, AlOH, is 0·97 per cent. Altogether, the comparison is fairly satisfactory.

One analysis by Riggs, that of the magnesium tourmaline from Hamburgh, N. J., I have omitted from my discussion. In that tourmaline there are variations which I cannot readily account for, unless by assuming the presence in it of a molecule

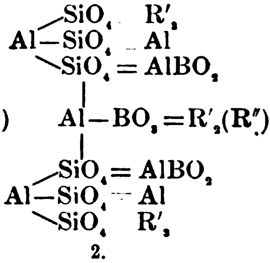
$$Al_5(SiO_4)_6(BO_2)_2 . BO_3R'_2 . R''_6.$$

Such a molecule, written structurally, exhibits affinities to garnet, rather than to the micas; and I prefer to await further evidence before committing myself to any definite formulation in this instance. As for the analyses published by Jannasch and Kalb, they fit in well with those of Riggs, and are amenable to the same treatment.

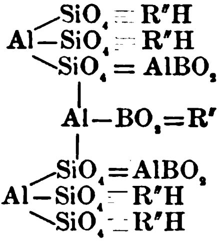
At first glance, some of the formulæ which I have proposed may seem to be complex; but they are all of the same type, and can be reduced to a few general expressions, as follows:



1.



2.



3.

These formulæ cover all of the established variations in the composition of tourmaline, they render the various replacements or isomorphous admixtures intelligible, and they indicate the directions into which the species commonly alters. There is one objection to them, namely, that one of the end products contains no alkali metal, and no alkali free tourmaline is known. The same objection applies to the Penfield-Foote formula, as will be seen by any one who attempts to apply it in the discussion of the iron tourmalines. Under either system of formulation the existence in tourmaline of alkali-free salts must be assumed.

One further possible advantage in the proposed formulæ remains to be pointed out. All of the chemists who of late years have discussed the composition of tourmaline agree in adopting the ratio between silicon and boron of 2 : 1, or $4SiO_2$: B_2O_3. And yet many of the analyses vary from this ratio to an extent which may not be due to experimental errors. For example, from among Riggs' analyses the following cases show large variations, the boron being too low. I give the silica and boric oxide as determined; the boric oxide as calculated from the silica by the accepted ratio, and the amount of variation between the two.

	SiO_2	B_2O_3 found.	B_2O_3 calc.	Diff.
Rumford, red	38·07	9·99	11·10	−1·11
Paris, black	35·03	9·02	10·22	−1·20
Monroe, brown	36·41	9·65	10·62	−0·97
Brazil, green	36·91	9·87	10·76	−0·89
Auburn, colorless ...	38·14	10·25	11·12	−0·87

In the analyses by Jannasch and Kalb the following examples are very striking:

	SiO_2.	B_2O_3 found.	B_2O_3 calc.	Diff.
Snarum	35·64	9·93	10·40	−1·47
Mursinka	34·88	8·94	10·17	−1·23
Buckworth	35·50	8·34	10·35	−2·01
Brazil	37·05	9·09	10·81	−1·72

It would hardly be wise to dismiss these variations as due to errors, especially when the summation of the analyses is good, and the analysts are known to be trustworthy. Such errors on the part of either Jannasch or Riggs would be almost incredible, and I am, therefore, inclined to believe that the analyses are good, and that we should seek a cause for the variations. In my scheme of formulation the bivalent group of atoms $=Al-BO_2$ occurs. Replace this in part by the similar groups $= Al-OH$ and $= Al-F$, and the variations are accounted for. This supposition satisfies the analyses completely, and covers the ground. It is in accord with all the evidence, even though its validity may not be definitely proved. By its application to the discussion of the analyses the divergencies between the calculated composition and the composition as found, can be notably diminished.

But although the formulæ which I have adopted serve to express the composition of all tourmalines, they still leave room for alternatives. Penfield and Foote, as well as myself, assume that tourmaline is a mixed salt containing distinct boric and silicic radicles. Future investigation may prove that it is really derived from a complex boro-silicic acid, as yet unknown; and the same conception may be true of other species, such as axinite, datolite, danburite, cappelenite, etc. A series of boro-silicic acids is theoretically conceivable; and until this question has been considered, the constitution of all the minerals above-mentioned must be regarded as unsettled.

Washington, April 19, 1899.
U. S. Geological Survey.

ART. XII.—*The Determination of Tellurous Acid in presence of Haloid Salts;* by F. A. GOOCH and C. A. PETERS.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIV.]

THE estimation of tellurous acid by oxidation with excess of potassium permanganate (either in acid or alkaline solution), destruction of the higher oxides of manganese or the manganate by standard oxalic acid in presence of sulphuric acid, and titration of the residual oxalic acid by more permanganate, has been shown by Brauner* to be feasible. The tendency of the permanganate to throw off too much oxygen when the oxidation is made in solutions strongly acidified with sulphuric acid (as must be the case if the tellurous oxide is to be held permanently in solution by sulphuric acid) necessitates the application of a considerable correction.† Fortunately, however, as has been shown in a former paper from this laboratory,‡ when the tellurous oxide is dissolved originally in an alkaline hydroxide and the solution made acid only to a limited degree with sulphuric acid either before or after oxidation by the permanganate, no correction appears to be necessary. Thus, when an excess of permanganate is added to the alkaline solution, followed by an excess of oxalic acid and sulphuric acid to an amount not exceeding 5^{cm^3} of the [1 : 1] mixture with water, the titration of the residual oxalic acid by more permanganate (after heating to 80° C.) leads to results which give no indication of over-decomposition of the permanganate; so also, when the process is similarly conducted excepting that before addition of the permanganate the original alkaline solution is acidified with sulphuric acid [1 : 1] to an amount 1^{cm^3} in excess of that necessary to re-dissolve the first precipitate, the results are theoretically accurate, and in close agreement with those obtained by the former procedure.

In the presence of free hydrochloric acid the action of the permanganate upon tellurous acid has been shown by Brauner§ to be irregular and excessive, and the irregularity cannot be corrected (as in the titration of ferrous salts in presence of hydrochloric acid) by the addition of a manganous salt according to the well-known procedure of Kessler‖ and Zimmermann.¶ So far as appears, however, there should be nothing to prevent the accurate determination of tellurium in tellurous compounds in the presence of chlorides by the permanganate process providing the first oxidation is made in alkaline solution, and the second oxidation carried out with such precautions as are necessary to a correct determination of oxalic acid by permanganate in presence of hydrochloric acid; for, the special danger of over-action on the part of the permanganate cannot exist while the solution is alkaline, and has passed when the tellurite has become a tellurate and before the solution is made acid. As to the proper conditions for the titration of oxalic acid by permanganate we have shown recently* that the presence of a manganous salt is necessary and sufficient to secure regularity of action when a considerable amount of hydrochloric acid is in the solution; when the amount is small —so much as would be formed in the decomposition of a gram or two of halogen salt of tellurium—the disturbing effect under ordinary conditions of work is probably inappreciable, but even in such a case it is better to work in the presence of a manganous salt for the reason that the titration of the oxalic acid may then be made at the ordinary atmospheric temperature.

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* Jour. Chem. Soc. 1891, p. 238.

† Loc. cit., p. 249.

‡ Gooch and Danner: this Journal, xliv, 301.

§ Loc. cit., p. 241.

‖ Ann. der Phys., cxviii, 48; cxix, 225, 226.

¶ Ann. der Chem., ccxiii, 302.

In the following table are gathered the results of experiments made with, and without, the addition of the manganous salt.

TABLE I.

O = 16, Te = 127·5.
Volume at beginning. 150$^{cm^3}$.
Temperature of titration, 60–80° C.

TeO_2 taken.	NaCl.	H_2SO_4 1 : 1.	$MnCl_2.4H_2O$.	TeO_2 found.	Error.
grm.	grm.	cm³.	grm.	grm.	grm.
0·1000	·4	5	....	0·1003	+0·0003
0·1000	·4	5	....	0·1000	0·0000
0·1000	·4	5	....	0·1004	+0·0004
0·1000	1·0	5	....	0·1003	+0·0003
0·0650	1·0	5	....	0·0653	+0·0003
B.					
Temperature of titration, 20–26° C.					
0·0700	·4	5·7	1·0	0·0705	+0·0005
0·0700	·4	5·7	1·0	0·0698	—0·0002
0·0700	·4	5·7	·5	0·0701	+0·0001
0·1000	·4	5·7	·5	0·1008	+0·0008

The tellurium dioxide, made by the careful ignition of the crystallized basic nitrate obtained by oxidizing tellurium with nitric acid, was dissolved in a small amount of sodium hydroxide, the halogen salt was added to the amount shown, the permanganate standardized against ammonium oxalate was run in until its characteristic color appeared, standard ammonium oxalate was added in excess of the quantity required to reduce the excess of permanganate, manganate, and higher oxides, and the solution was heated with enough sulphuric acid [1 : 1] to neutralize the alkaline hydroxide and have an excess of about 5^{cm^3}. In the experiments of Section A the liquid was heated to 60°–80° C. to dissolve the oxides at the final titration begun at that temperature; in those of Section B, manganous chloride (0·5 to 1 gram) was added, so that the reduction of the higher oxides of manganese and the final titration of the excess of oxalic acid might take place at the ordinary temperature of the room.

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* This Journal.

Plainly the presence of the chloride does not interfere materially in the determination of the tellurium by this process whether the titration is made at a high or low temperature.

It appears, also, upon putting the matter to the test, that fairly good determinations of tellurous acid may be made similarly in the presence of a bromide, provided the titration is made at the atmospheric temperature in the presence of a sufficiency (0·5 gram to 1 gram) of a manganous salt and of an excess of sulphuric acid limited to about 5^{cm^3} or less of the 12·5 per cent mixture. At the higher temperatures bromine is liberated at once from the acid solution by the permanganate. The experimental results are given in Table II.

TABLE II.

O = 16, Te = 127·5.
Volume at beginning, 150^{cm^3}.
Temperature of titration, 24°–26° C.

TeO_2 taken. grm.	NaCl. grm.	KBr. grm.	H_2SO_4 12·5 %. cm³.	$MnCl_2.4H_2O$. grm.	TeO_2 found. grm.	Error. grm.
[0·1000	....	0·5	20	1·0	0·1022	+0·0022
0 3000	....	1·5	25	1·0	0·3030	+0·0030]
0·0650	....	0·5	1	1·0	0·0661	+0·0011
0·0650	....	0·5	1	1·0	0·0647	−0·0003
0·1000	....	0·5	1	1·0	0·1002	+0·0002
0·3000	....	0·5	5	0·5	0·3010	+0·0010
0·0650	0·5	0·5	1	1·0	0·0661	+0·0011

It is obvious, therefore, that tellurous acid may be determined with a fair degree of accuracy by the permanganate method in the presence of chlorides and bromides, provided the first oxidation is made in alkaline solution and the final titration of the residual oxalic acid is made at ordinary temperatures in the presence of a manganous salt and restricted amounts of free sulphuric acid.

In the presence of an iodide, however, the case is different. Upon acidifying the mixture of iodide and the higher oxygen compounds of manganese, produced in the action of the permanganate upon the solution, iodine is at once set free, and oxalic acid does not suffice to reconvert it. In the presence of an excess of potassium iodide the higher manganic compounds are completely reduced with rapidity and the iodine liberated is the measure of the excess of permanganate over that required to oxidize the tellurous acid; the difference between the amount of permanganate thus indicated and that originally introduced should determine the amount of the tellurous acid. It is upon this basis that Norris and Fay* have founded their excellent iodometric determination of tellurous acid. This process consists in treating the alkaline solution of tellurous acid with standard permanganate until the meniscus of the liquid shows a deep pink color, then diluting the solution with ice-water, adding potassium iodide and sulphuric acid, and titrating with sodium thiosulphate. The results are excellent.

It is plain that any agent capable of converting the iodine to hydriodic acid without at the same time reducing telluric acid should be capable of measuring the excess of the permanganate, and so the amount of tellurous acid originally present. We find that the standard arsenite made, as usual, by dissolving 4·95 grams of pure resublimed arsenious oxide to the liter of water containing potassium bicarbonate answers the purpose admirably, and possesses the further advantage of fixing at once the entire standard of the process, the strength of the permanganate $\left(\text{approximately } \frac{n}{10}\right)$ being determined by running a definite volume of its solution into water containing potassium iodide (1 gram) with 2 to 3^{cm^3} of dilute sulphuric acid and titrating by the standard arsenite the iodine (set free by the action of the excess of permanganate and higher oxides) after neutralization with acid potassium bicarbonate. In this titration of iodine by the arsenite we find it best to dispense with the starch solution usually employed to secure the end reaction. The color of the free iodine itself is sufficiently definite, even at a dilution so much as 300^{cm^3}, and its disappearance under the action of the arsenite is much sharper than that of the blue starch iodide.

In Table III are recorded results obtained by adding the alkaline solution of tellurous oxide to 100^{cm^3} of water containing 0·5 gram or 1 gram of potassium iodide, introducing the standardized potassium permanganate until the green color of the manganate appears (about 30^{cm^3} of the $\frac{n}{10}$ solution for every 0·1 gram of TeO_2), adding a few cubic centimeters of dilute sulphuric acid followed, when the solution has cleared and separated iodine, by an excess of acid potassium carbonate, and titrating to the destruction of color with the standard solution of arsenic. It is essential in order that oxygen may not go to waste in the breaking down of the oxides, that more than enough iodide should be present when the solution is acidified to complete the reduction of the manganese oxides, or else, that the arsenious acid should be present in suitable amount before the sulphuric acid is put in. This latter procedure may be used in case, for any reason, it is preferred not to introduce more iodide into the solution than may be present originally: when, for example, a direct determination of the iodine present is to follow.

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* Am. Chem. Jour., xx, 278.

TABLE III.

O = 16, Te = 127·5.

TeO_2 taken. grm.	NaCl. grm.	KBr. grm.	KI. grm.	Total volume at end. cm^3.	NaOH present during oxidation. grm.	TeO_2 found. grm.	Error. grm.
0·1000	....	....	·5	160	0·1	0·1005	+ ·0005
0·1000	....	....	·5	160	0·1	0·1001	+0·0001
0·1000	....	....	·5	160	0·1	0·1003	+0·0003
0·1000	....	....	1·0	250	0·1	0·1007	+0·0007
0·2000	....	....	1·0	250	0·2	0·1997	−0·0003
0·1000	.5	·5	·5	250	0·1	0·1000	0·0000
0·2100	1·0	1·0	1·0	225	0·2	0·2105	+0·0005
0·1000	....	....	·5	160	1·0	0·1011	+0·0011
0·2000	....	....	1·0	300	2·0	0·2009	+0·0009

These results are reasonably good. Like those of Table I they would be brought practically in the average to the figure demanded by theory if the value of the Committee of the German Chemical Society, Te = 127, were to be taken instead of Te = 127·5, the value of Clarke and of Richards.

ART. XIII.—*An Iodometric Method for the Estimation of Boric Acid;* by LOUIS CLEVELAND JONES.

[Contributions from the Kent Chemical Laboratory of Yale College—LXXXV.]

IN a recent article,* I have described a process for the alkalimetric estimation of boric acid, depending upon the formation of a strongly acidic compound when boric acid and a polyatomic alcohol are placed together in solution. The method in brief consists in destroying the free mineral acid in a solution containing boric acid, by means of a mixture of potassium iodide and iodate, bleaching the liberated iodine by sodium thiosulphate, adding the indicator phenol phthalein and sufficient standard solution of caustic soda to give a faint alkaline coloration, bleaching by a small amount of mannite and adding caustic soda again to alkalinity, and thus alternating with mannite and alkali until the alkaline coloration produced is permanent. The amount of sodium hydroxide used represents the amount of acidity developed by the influence of the mannite upon the boric acid present, according to the hypotheses that the molecule B_2O_3 acts as two molecules of a univalent acid, HO.BO.

On making further study of this reaction, I have found that the acid developed by the combination of boric acid and mannite is, under certain definite conditions, sufficiently strong to liberate, quantitatively, from a mixture of potassium iodide and iodate, the amount of iodine required on the supposition that each molecule of metaboric acid (HO.BO) acts in a manner similar to a univalent mineral acid under the same conditions. ($5KI+KIO_3+6HOBO = 3I_2+6KOBO+3H_2O$.) Obviously, this reaction depends upon the behavior of the acidic boromannite compound as a strong acid, stronger than acetic, tartaric, or citric acid; for these acids have been found by Furry† to be incapable of liberating iodine regularly from a mixture of iodide and iodate. Conditions which tend to increase the acidic activity of this compound are concentrated solutions and moderately low temperatures.‡

Glycerine acts in general as mannite to produce acidic compounds with boric acid; and in a preliminary way, the relative acidity of the products formed by these two polyatomic alcohols with boric acid may be indicated by the results of two experiments in which the iodine liberated from a mixture of potassium iodide and iodate, proportionately to the time required for the liberation, is taken as a measure of the strengths of the acids developed.

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* This Journal, vii, 147.

† Am. Chem. Jour., vi, 341.

‡ Magnanini Gaz. Chim, xx, 428, xxi, 134, and Lambert, Compt. Rend., cviii, 1016, 1017.

Equal amounts (10^{cm^3}) of a standard solution of boric acid, prepared from the anhydride,* were drawn into separate Erlenmeyer flasks and a neutral solution of iodide and iodate added to each in an amount sufficient to liberate iodine in quantities corresponding to the acid used. One solution was treated with glycerine enough to constitute one-half the entire volume of the liquid: mannite (about 5 grms.) was added to the other. The thiosulphate required, immediately and after definite periods of time, is shown for each solution in the following table:

TABLE I.

B_2O_3 solution (10^{cm^3}) with mannite. Thiosulphate required.	Time.	B_2O_3 solution (10^{cm^3}) with glycerine. Thiosulphate required.
$18·60^{cm^3}$	immediately	$8·48^{cm^3}$
21·30 "	after 15 minutes	10·50 "
22·00 "	" 30 "	11·15 "
22·05 "	" 2 hours.	11·60 "

The solution of boric acid contained 7·706 grm. per liter. The thiosulphate was ·0999 normal. According to theory, the amount of thiosulphate required for 10^{cm^3} of the boric acid solution is $22·02^{cm^3}$. From these data we may observe that at the end of 30 minutes, in the solution containing mannite, practically the theoretical amount of thiosulphate had been used, while only about 50 per cent of that amount had been required to bleach the iodine liberated by the glycerine compound. Obviously, mannite forms with boric acid a more acidic compound than glycerine, and, from the indication given in the above experiments, may be relied upon, under certain conditions, to liberate the theoretical amount of iodine. If, from the iodide and iodate used to destroy the excess of mineral acid and already present, the boric acid, upon the addition of mannite does liberate iodine regularly—as the previous experiments seem to indicate—this liberated iodine should form a most convenient measure of the boric acid present.

On studying the conditions requisite for the complete liberation of iodine according to theory, several important points have come to light.

It has not been found possible under any conditions to rely upon the immediate liberation of the full amount of iodine: a certain period of time is required for the completion of the reaction. When the solution is of small volume and saturated with mannite, the reaction goes to the end most quickly—sometimes almost immediately—but there is this limitation which must be made emphatic, viz: that if the solution of boric acid is too concentrated—near saturation—the boric acid alone, when the iodate and iodide are added to destroy any other free acid present, throws out some iodine and on bleaching with thiosulphate a starting point is obtained at which some of the boric acid has already entered into combination. The amount of iodine thus liberated by the boric acid is, however, not large, and if upon the addition of the iodide and iodate, the iodine thrown out by the free hydrochloric acid present is immediately bleached by thiosulphate and the analysis proceeded with from this as the neutral point, even in concentrated solutions the error is almost inappreciable. If, however, considerable time intervenes between the adding of the iodide and iodate and the determination of the neutral point by thiosulphate, as much as several milligrams of boric acid may have liberated its amount of iodine and is, therefore, not capable of being registered by thiosulphate after the addition of mannite. This difficulty was not met with in those experiments in which the iodide and iodate were added at a dilution little greater than that of the standard solution used (7·738 grm. per liter), but in an attempt to estimate the boric acid in colemanite, where the solution was kept as concentrated as possible, hoping in this way to decrease the time required for the complete liberation of iodine, low values were obtained; that is, a false starting point was used.

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*The recrystallized hydrous boric acid should be fused in a platinum dish and, after cooling and breaking into small pieces, the desired amount placed in a small weighed platinum crucible and again fused until no more water escapes. After cooling and weighing, the boric oxide may be separated from the crucible, or with it placed in warm water, dissolved and made up to a definite volume.

The dilution found most convenient at the time of adding the iodide and iodate is not less than 25^{cm^3} for each decigram of boric acid (B_2O_3) present and should not be much greater than two or three times that amount. This limitation as regards volume is equally applicable, whether after obtaining the neutral point and treating with mannite, the boric acid is to be measured by a standard solution of alkali as before described or as here by the iodine liberated. As has been suggested, a large volume, even though saturated with mannite, prolongs the time of standing necessary and increases the effect of carbon dioxide upon the iodide and iodate present, for carbon dioxide, whether derived from the atmosphere or existing dissolved in the solution, upon standing, slowly liberates iodine. The amount, however, is small and, in the time required for the completion of the process, has never been found equivalent to more than a single drop of the solution of thiosulphate used. Even if the material to be analyzed contains carbonates, after acidifying in concentrated solution and shaking vigorously the small amount of uncombined carbon dioxide remaining has almost an inappreciable effect upon the results. The length of time required for the liberation of the theoretical amount of iodine in a solution of the volume suggested above, is 20 to 45 minutes, and at the end of 45 minutes standing in a solution saturated with mannite the reaction may be considered complete. During this period, however, it is well to keep the solution cool—at zero will do no harm—and shake occasionally to insure thorough mixture. The free iodine would tend to escape upon standing unless kept in a closed flask, but it is more convenient, immediately after the addition of mannite, to treat with an excess of the standard solution of thiosulphate—8 or 10^{cm^3} more than the amount required to bleach the iodine liberated, and at the expiration of 40 to 60 minutes titrate back with $\frac{n}{10}$ iodine. The strength of the thiosulphate solution found most convenient is $\frac{n}{5}$, while the use of iodine of one-half this strength $\left(\frac{n}{10}\right)$ enables the error of reading to be correspondingly diminished. In solutions of the volume recommended the addition of starch to give the indication with iodine is unnecessary and even detrimental, since a single drop of one-twentieth normal iodine in excess is sufficient to give a strong lemon coloration, while in the presence of starch an indefinite dirty red first appears and remains until the blue is brought out by the further addition of iodine.

With these observations in mind, a series of experiments was made in which the standard solution of boric acid was drawn into an Erlenmeyer flask, containing a small amount of free hydrochloric acid and made up to a definite volume. To bring the conditions to those of an actual analysis about 1 grm. of crystalline calcium chloride in solution was also added. Potassium iodate ($5–10^{cm^3}$ of a 5 per cent solution) and iodide ($3–5^{cm^3}$ of a 40 per cent solution) were added, and the iodine liberated by the hydrochloric acid, barely bleached and again brought to coloration by iodine. Mannite was added to saturate the solution, an excess of standard thiosulphate put in, and the solution set aside for various periods of time, at the end of which the excess of thiosulphate was titrated by iodine and the amount of unrecovered thiosulphate taken as a measure of the boric acid present.

The thiosulphate used was 0·198 normal and the iodine 0·0996 normal. The solution of boric acid contained 7·733 grm. per liter.

TABLE II.

B_2O_3 taken. cm^3.	Thio. taken. cm^3.	Iodine taken. cm^3.	Time of standing.	Volume. cm^3.	B_2O_3 taken. grm.	B_2O_3 found. grm.	Error. grm.
A							
28·00	32 00	1·88	0:30	28	0·2165	0·2168	+0·0003
27·03	32·00	4·37	0:27	27	0·2090	0·2081	—0·0009
27·02	31·97	4 04	1:00	27	0·2089	0·2090	+0·0001
B							
27·06	32·04	3·88	1:00	50–60	0·2093	0·2101	+0·0008
27·02	32·02	4·40	1:00	"	0·2089	0·2081	—0·0008
27·04	31·72	3·39	1:00	"	0·2091	0·2096	+0·0005
C							
27·01	31·53	2·88	2:00	"	0·2089	0·2100	+0·0011
26·05	31·01	4·01	3:00	"	0·2014	0·2025	+0·0011
D							
27·00	31·00	2·12	0:30	"	0·2088	0·2089	+0·0001
27·00	32·00	4·05	0:30	"	0·2088	0·2092	+0·0004
26·01	32·02	6·20	0:30	"	0·2011	0·2018	+0·0007
27·03	31·01	2·21	0:48	"	0·2090	0·2087	—0·0003
27·05	31·89	3·81	0:45	"	0·2092	0·2093	+0 0001
26·07	31·02	4·14	0:40	"	0·2016	0·2020	+0·0004
27·00	32·04	4.30	0:40	60	0·2088	0·2086	—0·0002

These results are so regular that the method seems worthy of high commendation, and especially since the standard solutions, thiosulphate and iodine, upon which the process depends, are so easily prepared and generally at hand.

The full method of procedure recommended is as follows: The borate is dissolved in as small volume and as little hydrochloric acid as possible, shaking well to remove free carbon dioxide and diluting so that, at the time of adding potassium iodide and iodate, there shall be approximately 25–50$^{cm^3}$ of solution for each decigram of boric anhydride present. The greater part of the excess of hydrochloric acid in the solution is destroyed by sodium hydroxide and the use of litmus paper, leaving the solution distinctly acid in reaction. Potassium iodide (3–5$^{cm^3}$ of a 40 per cent solution), and iodate (5–10$^{cm^3}$ of a 5 per cent solution) are added in excess of that required to liberate iodine in an amount corresponding to the hydrochloric acid and the boric acid present. The iodine liberated by the free hydrochloric acid is bleached by a small amount of a strong solution of thiosulphate, and after agitating to insure thorough mixture, iodine is added to faint coloration. Sufficient mannite is now used to saturate the solution—about 10–15 grm. for a volume of 50$^{cm^3}$—and sodium thiosulphate added in standard solution 8–10$^{cm^3}$ in excess of that required to bleach the iodine immediately thrown out by the mannite.

The solution is again brought to saturation, if necessary, by mannite and after standing in a cool place for 40–60 minutes, titrated with decinormal iodine to determine the excess of thiosulphate present. In the manner described, specimens of crude calcium borate and crystals of colemanite were analyzed with the results given below.

The solution of thiosulphate used was 0·19939 and the iodine 0·0996 normal.

Table III.

Calcium borate.

Mineral. grm.	Thio taken. cm³.	Iodine taken. cm³.	Time standing.	Volume of solutions. cm³.	B_2O_3 found. grm.	Per cent.
0·4015	35·05	4·75	1:00	40	0·2280	56·92
0·4010	35·34	5·23	2:00	45	0·2283	56·94
			Colemanite.			
0·4002	32·00	5·50	1:30	50	0·2043	51·04
0·2513	32·01	7·36	1:00	40	0·1279	50·91
0·4007	33·03	7·72	:50	65	0·2036	50·81

These results show little variation and in the case of colemanite correspond closely to the theory 50·97 per cent. The process is convenient, generally applicable and accurate within the ordinary limits of analysis.

ART. XIV.—*A Method for the Detection and Separation of Dextro- and Lævo-rotating Crystals, with Some Observations upon the Growth and Properties of Crystals of Sodium Chlorate;* by D. ALBERT KREIDER.

TWO properties of optically active crystals are available for their detection and separation. First, the sense of the optical activity itself, and second, the hemihedral structure which, in many cases at least, differentiates the enantiomorphic forms. While it is possible, in some cases, as in the separation of the dextro and lævo tartaric acids by the crystallization of the sodium-ammonium racemate, according to the method of Pasteur, to pick out the two sets of crystals by taking advantage of their hemihedral structure, this is rarely if ever the case with crystals of sodium chlorate, which in many respects is the most desirable substance to employ in certain investigations upon optical activity.

In these crystals it is only rarely that the hemihedral pyramidal face which distinguishes the dextro from the lævo form, is sufficiently well developed to enable one to distinguish thus between them. Indeed in not a single set of the many crops of crystals which the writer has grown has there been any considerable number of crystals showing even traces of this face. The crystals commonly grow in rectangular forms; these vary greatly in shape, some being cubical, but almost without exception they are flattened and very generally elongated, with the hemihedral faces rarely showing.

Dependence must, therefore, be placed upon their optical properties, and this involves the use of the polarimeter or polarization-microscope, both of which are expensive and unsatisfactory for this purpose, inasmuch as only one crystal at a time can be examined and even then for a decisive test must be of considerable size.

In the course of an extended investigation upon related subjects which involved the separation of the two kinds of crystals, some of the results of which have been published in a recent communication from this laboratory,* I have been impressed with the inconvenience and tedium of the methods usually employed. My efforts to devise some means of effecting the separation, which would be more expeditious and at the same time sufficiently delicate, have resulted in a very simple arrangement of apparatus the parts of which may be found in any laboratory and which makes it possible to examine a whole crop of crystals in a glance or to separate them with ease. Moreover, it permits of the examination or determination of the optical nature of the crystals during their growth or at the instant of their appearance, without disturbing them in the least; thus enabling me to decide a point which had previously been open to question. It is also more delicate than any polariscope I have ever used.

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* This Journal, vol. vi, p. 416, 1898.

The instruments employed for the determinations recorded in the article referred to were of the type in which a bi-quartz or half-shadow field is used, as in the well known Scheibler and Laurent polarimeters; various efforts to fit up something simpler having proved futile.

It is rather surprising to find others still employing the polarization-microscope for this purpose when the polarimeter is so much more satisfactory. After being adjusted to the tint of passage, a very small crystal simply held in the field of view by a pair of forceps or, if desired, moved from one to the other half of the illuminated disc, instantly and without further adjustment, reveals the sense of its rotation. But the objection to its use, as well as to that of the polarization-microscope, is that it necessitates the handling of each individual crystal of every crop, which when many are involved demands a great deal of time and labor.

The characteristic feature of the device which I proceed to describe, is a larger field of view than that of the other instruments, and one of uniform color of such a tint that when a mixture of the crystals is placed in it they assume different colors sufficiently striking to permit of their being easily distinguished and separated. It consists of two Nicol's prisms and some optically active substance, which latter may as well be a crystal of the kind to be experimented upon. I have also used quartz sections, but greater sensitiveness seems to result from the employment of the sodium chlorate crystal if it is sufficiently transparent. This will be appreciated as a perfectly satisfactory and economical substitute for the more difficultly attainable bi-quartz or simple quartz section, where the latter are not at hand. The crystal is mounted over the polarizer and observed directly through the analyzer. If the Nicols are crossed and the crystal then inserted between them, light will of course be transmitted, and if white light be employed, by rotating the analyzer, as is well known, the various colors complementary to that extinguished will appear in the order of the short to the long wave-lengths, if turned to the right, when a dextro-rotating crystal is employed and in the reverse order, if turned to the left; so that by suitable adjustment the desired color can easily be produced, as is explained below. If the crystal is thick enough, say one to two millimeters, this will suffice to reveal its nature; for if dextro, the blue color will appear shortly on turning to the right and if lævo, blue will appear by turning to the left.

However, this arrangement would not be sufficiently sensitive for smaller crystals and moreover necessitates adjustment of the analyzer.

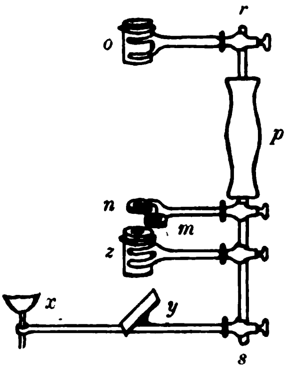
But if now the crystal is mounted over the polarizer, and the analyzer be so adjusted as to bring into the field the blue color and then turned *just* enough to cause the blue to merge into purple, a very sensitive field is obtained. All that is required then is to insert a crystal, ever so small, between the analyzer and "field crystal," whereupon either the blue will be restored or a deeper red obtained. In the first case the rotation of the crystal is evidently the same as that of the field crystal, and in the other case, the opposite. For larger crystals the change of color is only greater and not less certain in its evidence as to the optical properties of the crystal under investigation.

It is thus only necessary to select some clear and good-sized crystal whose rotation may easily be determined as above stated and then to use this crystal as the "field crystal." Without any change after the first adjustment above described, various crystals may now be brought into the field of view and the color they assume will instantly disclose their nature. This may be facilitated by spreading them on a long piece of glass, which may then be drawn through the field, and if it is desired to separate them, all those which, for example, turn blue may be picked out. This is extremely sensitive; the merest specks, if of the same rotation as the field crystal, being revealed. Those of opposite sense are less easily detected; but in using the device I have usually employed two field crystals of opposite rotation, separately mounted, as shown at *m*, *n*, fig. 1, so that either could be swung into the field and the analyzer adjusted. This however is only rarely desired and then merely for confirmation, where a considerable number of very small crystals occur.

The sensitiveness may be further increased by placing the very small crystal in the field and then turning the analyzer to and fro over the turning point of color, when the speck of a crystal, and its optical nature as well, will be revealed more easily by the color there preceding or lagging behind that of the field. In this way I have often been able to locate and study tiny crystals in the solution which were so small as to escape detection by reflected light.

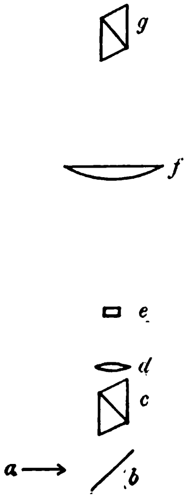
Fig. 1 illustrates the arrangements of the parts of the apparatus just described: *p* is a wooden handle through which passes the brass rod *r s*, to which are fastened the universal clamps *o* and *z*, which hold small, hollow, wooden cylinders turned to fit the mounted Nicols; *m* and *n* are respectively the dextro and lævo crystals of sodium chlorate, chosen for transparency and sufficient thickness, say 2 to 4^{mm}. They are mounted in cork discs which permit of either one being easily brought in or out of the field; *y* is a mirror which reflects the light from *x* vertically into the polarizer. By employing a long rubber tube to supply *x*, the apparatus is made portable and hence specifically adapted to observations of crystals during growth, by simply moving it so as to bring the flat-bottomed, shallow beaker containing the crystallizing solution between *o* and *n*. The beakers were held between two long supports which enabled one to see through the solution vertically; whence by simply moving the apparatus so as to include one after the other, observations could be taken without any disturbance of the crystallizing solutions.

1.



The most satisfactory arrangement, however, is that which I have employed to enlarge the field of view, so that a whole crop of crystals could be examined at once; the number of each counted or separated by pushing to one side or picking out, as desired. Here, as in the first form, the line of sight was vertical. Fig. 2 shows the arrangement of the parts, which were simply held by universal clamps to an upright rod. The source of light was an Argand or Welsbach burner, sending light in the direction from *a* to the mirror, *b*, which reflects the light vertically into the polarizer, *c*. Upon the Nicol was placed a double convex lens, *d*, of short focal length, and in its focus was fastened the field crystal, *e*, of sodium chlorate mounted in a disc of cork. Thus all of the light was subject to rotatory polarization and formed a strongly diverging beam. Where the cone of light had a section of about 7 or 8^{cm} in diameter, a plano-convex lens, *f*, of longer focal length, was placed, with the plane side up, and upon this was laid a sheet of glass, which acted as a table for the crystals to be investigated. Thus the light was spread and again converged, the crystals occupying the broadest part of the illuminated path. At the focus of the light from the second lens was placed the analyzing Nicol, *g*, through which the crystals were viewed directly, by bringing the eye close to *g*. Upon turning the analyzer, the

2.



crystals undergo the expected change in color and are beautifully differentiated. During the turning they may all change color, but never so as to leave the result uncertain. For it is evident that, if the field crystal is selected so as to be thicker than any of the regular crop, the crystal examined can only increase or diminish its effect but never reverse the rotation. Hence the blue color will only appear at the two characteristic points in rotating the analyzer through 360°. But if this condition is not fulfilled, then a thicker crystal of opposite rotation would, at some point, turn blue, just as would a crystal of the same rotation whose thickness was the difference between the field crystal and the one under consideration. Usually the field crystal was 3 or 4^{mm} thick. The crystals grown rarely exceed this thickness, and if they do, their determination affords no difficulty by the simple use of the two Nicols as before stated.

If the analyzer be adjusted so that the smallest of the blue crystals is distinctly blue, then if the field crystal is 3^{mm} thick, a crystal of the same kind 10^{mm} thick would still have a bluish tint in this field, while a lævo crystal of that size would be distinguished by a yellowish tint, or at least lack the bluish tint. This of course is an extreme test, the crystals never growing to that thickness under ordinary conditions: but it gives some idea as to the range within which the detection may be made.

Manifestly, the greatest efficiency of this device would only be obtained when the crystals under examination are shielded from diffused light: which, in my work, was accomplished by aid of a piece of dull black paper, or by working in a moderately dark room.

The Growth of Crystals.—It may be worth while here to add some of the results which the writer has obtained in a little investigation of the causes which determine the resultant optical activity of a crop of these crystals, to which Professor Japp's inaugural address, and the discussion to which it gave rise, adds some interest.

First, I have to add to the evidence adduced by Marbach,[*] Grenez[†] and Landolt[‡] in favor of the optical neutrality of the ultimate molecule of sodium chlorate, the results of a number of experiments in which, starting with only one kind of crystal, I have obtained, by repeated recrystallization, successive crops of crystals whose resultant rotations, i. e., the excess of dextro or lævo forms, bear no connection whatever with that of the original lot. For example, I have selected a number of pure dextro crystals and allowed their solution to crystallize by spontaneous evaporation. The dextro and lævo crystals of the crop were then separated, counted and weighed; after which they were again mixed and dissolved. These were then allowed to recrystallize and the whole process repeated. But the

[*] Pogg. Ann., xci, 487. [†] Ber., xxix, 2, 2410. [‡] Compt. Rend., lxvi, 855.

results were in no respects different from those obtained when an equal quantity of both crystals were taken at the start. The same was done with lævo crystals and with a number of independent lots. In one case, starting with pure lævo crystals, a crop having eighty per cent of dextro crystals was obtained and upon recrystallization gave an excess of lævo. To record the results in detail, is hardly worth the space. It may simply be said, that there is no connection whatever with the optical activity of the original crystals and that of the new crop. This will of course be true only when the crystals are thoroughly dissolved or the solution filtered before recrystallization, since any nucleus left in it would affect the result, as the following experiments prove.

In the second case, as has previously been pointed out, when a crystal of one kind is placed in a saturated solution, the resultant optical activity of the crop of crystals is always the same as that of the crystal inserted; the percentage, however, seems to depend upon the rate of precipitation. This seems to point to the influence of the first crystal formed, as the cause of the excess of one or the other kind in the crop. To further investigate this, I have grown crystals by carefully observing the optical properties of the first one formed. The apparatus illustrated in fig. 1 is admirably adapted to this purpose, since it permits of the observations without the slightest disturbance of the crystallizing solution. Owing to the irregularity in the rate of formation of the crystals under varying conditions of temperature and humidity, a series of such results is tedious and difficult; demanding the continual presence of the observer, in order that the determination should be made at the moment of the appearance of the first crystal. For example, one experiment which was started at noon by filtering a portion of a saturated solution—in this case one which had stood over an excess of crystals for several weeks and had been well shaken several times daily—had formed no crystals by 9 o'clock of the next day; though by 10.30, nine fair-sized crystals had developed. In other cases they appeared during the same afternoon or night. Moreover, any particles of dust settling on the solution form nuclei, about which clusters of crystals are apt to develop and in such cases grow more rapidly than those under the liquid, though the latter may have been first to appear. The conclusion of many experiments was prevented in this way, as well as by the simultaneous appearance of a number of crystals. However, by taking precautions against dust and by securing approximate uniformity of temperature, etc., a number of experiments were successfully concluded: and in every single case where the first crystal formed developed appreciably before others appeared, the resultant activity of the crop was invariably that of the first crystal.

Sloane Physical Laboratory.
Yale University, July 1, 1899.

ART. XV.—*The Devonian Interval in northern Arkansas;* by HENRY S. WILLIAMS.

IN numerous places in northern Arkansas the evidences of an unconformity separating the Silurian from the overlying Carboniferous are very clear. In some cases there is no rock-material separating these two grand terranes. In other cases there are greenish shales, or coarse sandstone, with polished grains and rounded nodules of black shale; and in the western sections the interval is occupied, in part, by a black shale, the *Eureka shale* of the Washington County report.* The sandstone when present is called the *Sylamore sandstone* in the various reports. The materials discussed in this paper are from the following localities. The numbers before the names are locality numbers of the United States Geological Survey, under which the materials studied are catalogued preparatory to final deposit in the National Museum.

1246.	Buck Horn, Stone Co., Arkansas.	1238.	St. Joe, Searcy Co.
1281.	Roasting Ear Creek, Stone Co.	1277.	Cave Creek, Newton Co.
1278.	Rush Creek, Marion Co.	1410.	Eureka Springs, Carroll Co.
1282.	Dodd City, Marion Co.	1279.	War Eagle Creek, Washington Co.
1414.	Long Creek, Searcy Co.	1291.	Buffalo Fork, Newton Co.

On passing westward from Batesville, the first locality, from which specimens representing this interval have come, is 3 miles north of Buck Horn, Stone County (No. 1246 A) on Cagen Creek.

No. 1246. Buck Horn, Stone Co.

This station was first reported by Dr. Branner as "section 3, 14 N., 9 West, at John Greenway's; over 4 feet black shale overlaid by one foot that weathers red." It is 82/11 of Hopkins's report of '89, Oct. 3d; and was reported by me in letters Nov. 9, '89, as "a black shale very similar to the Berea of Ohio." Afterwards, Mr. Stuart Weller was sent into the region and reported the exact sections from Cagen Creek, 3 miles north of Buck Horn, July 13, 1891.

Study of the fossils in connection with the sections resulted in the following interpretation, viz:

1246 A3. A red marble = St. Joe marble. (= Eocarboniferous.)
A2. Black shale with Lingulas, several feet thick. (= Eureka shale.)
A1. A pink marble with no fossils seen, probably the Polk Bayou limestone. (= Trenton).

This section is in the hollow on the south side of the creek. The section B was made 200 yards east of A; and B′ = A′;

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* Ann. Report, 1888, vol. iv, p. 26.

B2 = A2, but B2 is a hard, greenish black rock with rounded black pebbles; B3 = A3. The 3d section is taken at a point about half a mile up the creek, on the east side. C1, 2 and 3 correspond to A2; and consist first of black shales, with a band of hard black limestone 4 inches thick (C2) in the midst. This is followed above by the St. Joe marble (C4), and is capped by Boone chert (C5).

At the Buck Horn locality the interval, between the pink Silurian limestone which contains no fossils and the overlying red Carboniferous marble, contains a few feet of typical black shale, such as represents the Devonian interval in Tennessee. It contains a small Lingula which may be called *L. spatulata*, until some one succeeds in determining where to draw the specific limit between the minute forms of the Genesee shale of New York and the several forms which succeed it in the black shale strata of the Waverly of Ohio.

Associated with the Lingula are Conodonts, as in the Genesee and similar shales in New York state. Two hundred yards east of this section (at 1246 B), the same interval is occupied by a hard, siliceous, greenish-black rock with very hard, rounded black nodules, with no fossils seen. In both of these interval-filling rocks are found the coarse, polished, siliceous grains so characteristic of the Sylamore sandstone, indicating identity of origin for the three kinds of material. The black shale may be called the *Eureka shale*, stratigraphically speaking; but its identity paleontologically has not heretofore been established.

The next place from which evidence has been seen is Roasting Ear Creek, 8 miles southeast of Big Flat, in the western part of Stone County.

No. 1281. Roasting Ear Creek, Stone Co.

The materials examined from this section were collected by Weller, from a point 8 miles southeast of Big Flat, July 10, 1892. The fossils in the red limestone (A1) were supposed by him to have fallen down. They are all Trenton fossils, showing the rock to be the Polk Bayou limestone. The shale (A2) contains the same kind of black pebbles seen in 1246 B2.

Here the interval-filling material is a green siliceous shale, more or less calcareous, containing fragments of shells and of what appears to be broken fish teeth, and well-rounded pebbles or nodules of hardened black shale; everything too much broken and polished to indicate the genus or even class of organisms with certainty. This rests immediately upon red marble of Trenton age, the Polk Bayou limestone. The overlying rock is not reported.

About twenty-five miles northwest of this section is seen another outcrop at the "narrows," 3 miles from the mouth of Rush Creek, in Marion County.

No. 1278. Rush Creek, Marion Co.

The section 1278 was taken along the creek, opposite the mines, by Weller, July 9, 1891. The limestone (A2), coarse-grained, pinkish, containing Trenton fossils, is thus shown to be the *Polk Bayou limestone.* The limestone below (A1 and B1) is probably the same as the heavy bedded blue limestone, and, though no fossils are seen in it, the probability is that it is the *Izard limestone* of the Reports. The coarse saccharoidal sandstone (A3 and B2) is the *Sylamore sandstone.* The red marble (A4 and B3) contains a few fossils of Carboniferous age, and is therefore the *St. Joe marble* of the Reports. Section 1278 B is taken on the hill, three miles from the mouth of Rush Creek. The evidence that the Sylamore sandstone represents the Black shale (Eureka shale) is clear upon comparing the sections 1278 and 1246. This interval-material is pinched out to almost nothing in the following section.

Another section was seen at Dodd City.

No. 1282. Dodd City, Marion Co.

The section reported was taken at a point 3 miles north of Dodd City, Durst's spring, by Weller, July 23, 1891. He reported that the red marble (A3, *St. Joe marble*) rests directly upon the blue-gray limestone (A2), which contains fossils showing it to be the *Polk Bayou* (Trenton) limestone. Below it is a bed of the Ordovician, *Saccharoidal sandstone.* No rock was discovered in the interval, but the gap was seen separating the two limestones, and the upper one is identical (so far as the characters of the limestone, without actually seeing fossils, can be depended upon) with the St. Joe marble of the other sections. We see here a case of a true interval, representing all the time from the Trenton to the Carboniferous, certainly later than the Chouteau, and without sufficient disturbance of the horizontality of the rocks to make the unconformity apparent.

A few miles west of the Roasting Ear Creek section, on Long Creek, near a place called Providence, Searcy County (1414 A), is seen another section, with the Silurian terrane terminated by *St. Clair limestone*, and then about two feet of interval, filled with characteristic *Sylamore sandstone* with its polished siliceous grains, and black rounded nodules.

No. 1414. Long Creek, Searcy Co.

This section, taken along the bank of the creek, was visited by Dr. Branner and myself; and when it was first seen, it was quite impossible to imagine that the two limestones were not actually continuous. The beds lie nearly horizontal, and a stretch of their exposed edges is in sight for several hundred feet. The interval (A2) was discovered only after search. The fossils in the limestone (A1) belong to the Niagara fauna of the *St. Clair limestone.* The *Sylamore limestone* (A2) wears away faster than the limestone and shows a retreat in the ledge of exposed rocks. When examined, it is found to be the typical Sylamore sandstone composed of polished sand grains, and pebbles of black shale and fish-bone fragments. Immediately above it comes, without apparent change in the plane of bedding, the *St. Joe marble* (A3) containing Carboniferous fossils.

Still further west is the St. Joe section.

No. 1238. St. Joe, Searcy Co.

In this section, the green shale, associated with the Sylamore sandstone (A4 and 5), contains nodules like those in the sandstone; and the Lingulas contained in them, and fragments of Lingulas in the black nodules, point to a common origin for the varying kinds of deposit, i. e., black shale, Sylamore sandstone, and this green shale containing the black nodules. A piece of large fish-plate indicates the age to be as late as Devonian, but, in itself, does not make certain that it may not have been late Devonian, though the probability is that it belongs below the latest Devonian. At this point the termination of the Silurian terrane (A2) is Trenton limestone (Polk Bayou limestone). The interval material is, first, a few feet of green, gritty mud shaly rock (A4), including a few black, rounded, hard nodules, its upper part shaly, followed by four inches of Sylamore sandstone (A5), with its characteristic polished siliceous grains and black worn nodules. The nodules are slightly calcareous, due either to infiltration of calcite, or included fragments of shell. Some of the nodules contain pieces, and whole shells of Lingulas, but the structure of the nodules suggests agglutination. In one of them a grain of the polished silica is enclosed; and in another the nodule is made up of fragments of shells and oolitic grains. The sandstone is followed above by a compact, red Carboniferous limestone (A6) of thirty feet thickness. The under surface of this limestone, where it came in contact with the interval sandstone, is penetrated by, or contains black nodules like those below; two specimens were obtained partially surrounded by the crystalline limestone. The Lingula is like a minute *Lingula spatulata* of the New York black shales, but is rather shorter and more solidly formed than the ordinary type of *L. spatulata.* However, the variability expressed in the few specimens examined leaves no mark for differentiating it specifically from *L. spatulata*, as seen in sundry localities in the north.

In one piece of the Sylamore sandstone, a large fragment of a fish-plate was found, reminding one of the plates of Dinichthys of the Black shales of Ohio. But the piece is worn and crushed, and its original outlines are indistinguishable. The bony texture is preserved, and the fragment, 2 by 3 inches in diameter, is ¼ to ½ inch in thickness.

In Newton County, a section was seen near the Saltpetre Cave, Cave Creek P. O.

No. 1277. Cave Creek, Newton Co.

The first specimens seen from this section were collected by Mr. Hopkins in the summer of 1890, and were marked as from Saltpetre Cave at Cave Creek P. O. In the next season Mr. Weller collected from the same section, sending in enough specimens to make out the several elements of the section. The interval-material of this section is a hard, black, shaly rock, about 18 inches thick (A2) separating the Polk Bayou limestone (A1) from the overlying red marble (A3), the St. Joe marble, which is here 10 feet thick; above it lies the cherty limestone (A4), which is called Boone chert in the Reports. The black shale (A2) contains Lingulas as in the St. Joe section.

The typical locality for the black shale is Eureka springs, from which the formation derives its name.

No. 1410. Eureka Springs, Carroll Co.

The full section of the rocks at Eureka Springs is given in volume iv of the Annual Reports of the Geological Survey of Arkansas for 1890.* The part of it interesting in this place is that given in my section 1410 A. A′ is the top of the saccharoidal sandstone; resting immediately upon this and without any apparent change in the plane of bedding is the black shale (A2). In the section, in the midst of the city, the thickness of black shale is about four feet, with a foot above it of green shale. In some places the green shale is several feet thick. When I visited the locality, an excavation for the cellar of a building exposed a fresh cut of about six feet of the greenish shale, from which a few fossils were obtained. The black shale ran up into the green without any sharp line of sudden change, showing a continuous deposition. The black part is, however, the typical Eureka shale (A2), while the upper green part is a representative of the formation which in Tennessee is much more important and constitutes in that region the lower member of the Carboniferous system. The sandstone (A′) below the Eureka shale is the Ordovician rock lying below the Polk Bayou limestone. It will be noticed that where the black shale, filling the interval, is present and thickest in the northwest it rests on the lower formations, below the Polk Bayou limestone, and the erosion has cut into the saccharoidal sandstones. It seems probable that these sandstones were the source of the polished siliceous grains characteristic of the Sylamore sandstone, and if this be a correct inference, a reason is apparent for the distribution of the Sylamore sandstone over surfaces which had not eroded so far down as this rock; since the place of sedimentation would not be the same with the place of erosion from which the materials were derived.

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* Marbles and other limestones, by T. C. Hopkins. 1893.

Further south, in the northeast corner of Washington County, Arkansas, specimens have been obtained containing a few indistinct fossils which are important in interpreting the age of this interval-deposit.

No. 1279. War Eagle Creek, Washington Co., T. 18 N.,
R. 28 W., Sect. 15.

The materials were collected by Mr. Weller, and the section is described as a bed of black shale (1279 A′) with very little iron pyrites, containing fossils, followed immediately by a reddish-gray limestone (1279 A2) containing crinoid stems, but no distinct fossils. On the opposite bank, the black shale was found to be about 30 feet thick, but no fossils were discovered in it. The underlying rock was not seen. According to the map and descriptions given by Prof. Simonds,* this is the Eureka shale underlying the Boone chert and limestone. The fossils are in imperfect, frail and crushed condition, but have a decidedly Carboniferous aspect. They also appear to belong to the same fauna, discovered in the greenish shale (1410 M2) into which the black shale of Eureka springs gradually merges before reaching the limestone above.

Three small collections from Newton County (1291 A, B and C) indicate the same fauna in greenish shale, and the several, together, present unmistakable evidence of the Chouteau fauna of the regions further north in Missouri.

No. 1291. Buffalo Fork, Newton Co.

The materials from this region were collected by Mr. G. H. Ashley, and the localities are defined as follows, viz:

1291 A. Eureka shale, from N.W. quarter to S.W. quarter, of section T. 17 N., R. 21 W.
1291 B. At base of St. Joe marble, probably; 4 miles south of Jasper, in Henson Creek, one mile above mouth of Panther Creek, S.E., of N.W., Sect. 1, 15 N., 22 W.
1291 C. In shale on top of Saccharoidal sandstone, N. 4, of S.W., Sect. 9, 16 N., 22 W.

The fauna of the interval-filling material.—Although the fossils, obtained from the black shales, the greenish shales following them, and the nodules contained in the black shales, are very rare, imperfect and frail; a careful study of the material has brought out features more or less distinct by which their biological relations can be determined. The whole of this list may require some specific revision whenever better specimens come to light, Enough is preserved to make the generic identifications fairly certain. In determining them, great pains was taken to discover, if possible, signs of those particular characters which mark the difference between closely allied species of successive, known geological horizons. A few remarks may be given regarding the points thus ascertained regarding the more important genera.

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* Ark. Geol. Survey, Ann. Rept, 1888, vol. iv, Washington County, by F. W. Simonds.

Lingula.—In the black shale strata, and in the black nodules of the greenish shales and Sylamore sandstone, a number of minute Lingula were seen. These were compared with a large series of specimens from the typical Genesee shales of New York, Cleveland, Bedford, Berea, Ohio, Huron, Portage, Ithaca black shales, Harpeth shales of Tennessee, and from similar black-shale rocks of Europe. The conclusion from the study is that the forms common in the Genesee black shales of New York are the central and typical forms. These are often found almost alone. The most frequent associates are Conodont teeth and a small Chonetes. From these common black-shale forms the succeeding Lingulas differ by slight and indefinite gradation, until they reach a size five times as great as the typical Genesee types, and vary in dimensions and in thickness of shell.

The change, which is apparent in the New York sections, when the succession is distinct and clear, is from the very minute forms in the pure Genesee shale, to larger, broader and more rounded forms in the same shales; the variation in the Genesee specimens reaches a doubling or tripling of the typical size, and with modification in the general form. In the blackish shales higher up at about the Ithaca horizon, and in Portage strata when they are prevalent, and still higher in bands of shale coming in in the midst of Chemung strata, in western New York, the larger, broader, more rounded forms are seen. In the black shales in the Ohio sections, representing the upper part of the Chemung and reaching up into undoubted Carboniferous horizons, the same form is traced, increasing somewhat with the rise in horizon and as they mix with other species. Finally, we reach a form, which is represented fairly well by Meek and Worthen's *Lingula subspatulata.* The fact that the subspatulata size and form are reached in the prevalent Tennessee type has led me to think that where it occurs the horizon is well up in the series rather than in a mesodevonian horizon.

In the Arkansas case, the forms seem to me to come in near the upper limit of the Devonian, as expressed in the New

York-Ohio region, on the supposition that the modification from the minute forms to the broader, oval, flat, enlarged forms of the Carboniferous horizons is one due to gradual evolution. But I do not feel perfectly confident that this is the case. I think it more likely that the conditions of environment at the same time would find expression in something of this modification. That the species is peculiar to the kind of sediments which, in their purity, constitute the black shale, is quite evident from a wide study of their occurrences.

Cyrtina.—In the brownish-black shale of station 1279 A1 several specimens, which I refer to *Cyrtina acutirostris* Shumard, are found. Several of the specimens are much crushed, but the high beak, the attenuated upper part, and broad and rather extended mesial sinus and few lateral plications, which are not so broadly rounded as in the figure, are the characters suggesting the species. The characteristic punctations are not evident.

Spirifer.—Several species of this genus are recognized. The specimens from 1291 C (Y 200) are clearly *S. marionensis.* Those from 1279 A1 (Y 423) are crushed and only fragments, but what is evident agrees with the similar parts of perfect specimens of *S. marionensis.* This species is frequently seen in the higher beds and across the line in Missouri; it is characteristic of the corresponding shales at the base of the Carboniferous. *S. biplicatus* Hall is suggested by some crushed specimens (Y 171), but the material is too imperfect for certain identification. *S. winchelli* Herrick, cf. *S. mesacostalis*, a very perfect specimen (Y 199), resembles very closely some specimens of the smaller variety of *S. mesacostalis* from the Ithaca group (Devonian) of New York. It is the type described by Herrick, from the Waverly of Ohio, under the name *S. winchelli.* Mr. Herrick suggests the close resemblance to *S. mesacostalis*, but in a note to the writer he says that Professor Winchell considered it to be undoubtedly a distinct species.

S. ? compactus Meek.—Some crushed specimens (Y 172) from the green shales at Eureka springs (1410 M2) may belong to this species. It has the form of *pinguis* or *suborbicularis* Hall, and yet is too crushed to well make out the true proportions.

Spiriferina ? octoplicata.—Specimens (Y 173), fairly representing the character of this species, occur in the green shale at Eureka Springs (1410 M2).

Athyris is represented in the green shales (1291) by specimens, which are referred to *A. hannibalensis* Swallow (Y 201). Another specimen is referred with doubt to *A. fultonensis* Swallow, from the green shales of Eureka Springs (1410 M2).

Chonetes.—Two, and perhaps three, species of Chonetes occur in these shales.

C. illinoisensis.—A single specimen of this species occurs in the soft green shale (1410 M2), above the black, at Eureka Springs. It is smaller and more delicate than the typical forms of the species, but has the broad, flat, finely striated characteristics of *C. illinoisensis.* With it are associated many smaller forms, which may be of two or one species; the larger number are about the size and shape of the New York *C. scitulus,* but varying to the shape of *koninckianus.* There are other specimens with fewer plications, which approach the character of Shumard's *C. ornatus.* It is altogether probable that the specimens described as *C. ornatus,* Shumard, are the same species with these. There is considerable range of variation among the specimens before me, and it seems not impossible that they all may represent a very variable species; since the larger forms are more finely striate by bifurcation of striæ, and are flat and frail, as in the largest form which I have referred to *C. illinoisensis.* For purposes of reference, until a fuller study of the genus is made, they may stand as *C. illinoisensis, ornatus* and *? scitulus.*

Productus.—One fragmentary specimen from the green shales (1291) (Y 204), though too imperfect to specifically identify, is distinctly a Carboniferous type, resembling *P. burlingtonensis* Hall.

Productus hallanus Walcott, is represented by several specimens from the green shale at Eureka Springs (1410 M2), and from the black shales at War Eagle Creek (1279 A1).

The genus *Rhynchonella* is represented, but the crushed specimens make specific identification little better than guesswork. Their resemblance to similar crushed specimens, in the Tennessee greenish shales in the same geological position, and in the Waverly of Michigan and Ohio, which are generally referred to the species *R. sageriana* Winchell, leads me to so label them. These frail, crushed Rhynchonellas are from the Eureka green shales (1410), and from the black shales at War Eagle Creek (1279). *R. acuminata* var., is also seen in the green shales in Newton County (1291).

Orthidæ.—Of this family, several genera are represented. *Rhipidomella* (Oehlert) is represented by forms which are generally catalogued under the name *Orthis michelini* L'Eveillé; but, though crushed, the specimens before me are decidedly broader than that species, and thus are more like the Devonian types of *O. Vanuxemi* or *penelope.* In outline, they are close to that of *O. Oweni* Hall,* but have no trace of the broad fold and sinus of that species. They are evidently the same species figured on Plate VI A of the New York Volume VIII, Brachiopoda I, and called *Orthis sp.?* (compare *O. penelope*), from the Waverly group of Granville, Ohio.

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* Paly. N. Y., vol. viii, Brachiopoda I, p. 342, fig. 19 of plate vi.

As a name, I think it is probable that Hall first distinguished the species in question, in the Iowa Report of 1858,* under the name *Orthis michelini, var. burlingtonensis*, so that they should be called *Rhipodomella burlingtonensis* Hall. The specimens correspond more nearly to specimens in like condition in the Burlington than to the typical *O. vanuxemi* or *penelope*, though in some features recalling the latter. Another species, *Rhipidomella thiemii* (White), is a small species, and may prove to be but a young or small form of the *burlingtonensis* species, but, as it is frequently seen of the diminished size, it is safe to refer to it as a distinct species.

Schizophoria is represented by a couple of faint impressions in the black shale of 1279 A1 (Y489). This, for purposes of identification, may be referred to *S. swallowi* Hall, with a query; sufficient evidence is present to refer it to this genus, but the crushed condition of the specimen makes it impossible to tell what its original form was.

Strophomenidæ.—Among the Strophomenidæ, a few distinct representatives of the *Leptæna rhomboidalis* have been seen in the green shale of 1291.

Terebratuloid shells are difficult to identify, even when perfect, from the exterior alone, but a crushed fragment in the green shale of (1279 A1) suggests strongly the form *Dielasma burlingtonense.*—We may refer to this as a possible species of the fauna.

In addition to the specimens whose generic affinities may be distinguished, there are *Conodont teeth*, fragments of *fish bones* which must have belonged to large mailed fish, and *Crinoid stems.*

When the whole fauna is critically examined, though the specimens are nearly all in very imperfect, distorted condition, enough may be made out of their zoological affinities to settle the question of general horizon. The black shale, when it stands out distinct with a limestone below and above, presents a fauna which would link the horizon with that of the Genesee black shale of New York. But when we examine it, where followed gradually by a green shale, becoming finally calcareous, and running up into thin, shaly limestone beds with the green shale alternating with it, before the pure limestone enters the section, the evidence of precise horizon is less positive. In such a case the fact, that the Genesee black shale has a definite geological horizon in the New York sections, must not be allowed to limit the range of the fauna it contains. The fauna, which is well exhibited as soon as the green shales are in force, is always of Carboniferous type; and in one case, we have a black shale also containing the same fauna, which I refer to the black shale of the War Eagle Creek section (1279 A1), thus clearly indicating the stratigraphical continuity of the green and black shales of the general region.

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* Geol. of Iowa, vol. i, part 2.

The fauna associated generally with the pure black shale sediments in Arkansas, and in other regions in the south, is restricted to very few species, of which the Lingula is the most frequent often associated with Conodont teeth. This is also characteristic of the Genesee black shale of New York. My conclusion from the study of the whole problem is, however, that the fauna of the Genesee black shale, which has a definite limited position in the New York section, is a fauna of wide geological range, and is characteristic of the black shale conditions of sedimentation rather than of the particular limited horizon represented by the Genesee formation. The fauna in these fine shales in Arkansas, terminating and following the black shales, is unmistakably much higher than the Genesee black shale of New York. Faunally, it is the correlative of the Louisiana or lithographic limestone, and is thus as late as the Kinderhook stage of the Eocarboniferous.

There can be no doubt regarding the Carboniferous age of the faunas of the typical Louisiana limestone. Its fauna is characteristically Kinderhook, Waverly, Chouteau, and it is not paleontologically correct to refer the Louisiana and Hannibal (or those Arkansas formations which belong to the same epoch) to the Devonian (as Mr. Keyes has done in the Biennial Report of the State Geologist of Missouri for 1897, page 59). The fauna of the shales terminating the interval deposits in Arkansas, is evidently the same as that seen in a similar position in the Louisiana section in Missouri, and thus belongs to the base of the Chouteau or Kinderhook group.

The age of the Sylamore sandstone and associated deposits.—From a study of all the evidence visible, both stratigraphical and paleontological, I have reached the following conclusions regarding the probable age of the formation of this interval-material. The distinct fossiliferous deposit of black shale seen in Cagen Creek section (1246 A) cannot be distinguished paleontologically from the "Black shales" of the Tennessee, Kentucky and Indiana sections. The St. Joe sections indicate distinctly that the green shale and the Sylamore sandstone were formed at the same geological time, i. e., consecutively; and that the Carboniferous deposit, following, was formed after the Sylamore sandstone was laid down, hence that the sandstone with its nodules, and the green mud-shale associated with it, are not later residual products of decay of the lower limestones, as Mr. Penrose explains the origin of the manganese-bearing interval-material in Independence County. Again, the black nodules contain Lingulas as do the black shales, and the structure of the nodules, and the evident agglutination of some of them, and the concretionary nature of the oolitic grains of which others are composed, all point to a concretionary mode of formation rather than to a simple rounding of broken fragments; while the extreme polishing and medium size with absence of finer grains of the sandstone, point to excessive erosion. Again, the fauna appearing next above this interval-material is in all cases, when covered by rock, of Carboniferous age; the species indicating generally a Chouteau fauna, in some cases later Chouteau with traces of Burlington, or Keokuk species.

The interpretation of these facts is that the typical interval-materials, the green shale and the Sylamore sandstone, were deposited after the period of the formation of the typical black shales which, along the borders of the Ozark uplift, was terminated, or actually driven outward, by the elevation of the region; that these particular deposits mark the stage of sinking again of the land and the resultant erosion which introduced the Carboniferous formations for this region; that the time was at the very close of the Devonian and beginning of the Carboniferous eras. I conclude that the explanation of the varying age and nature of these deposits is due to the sections having been taken at places at lower or higher position on the gradually sinking land, and expressing the overlap of the successively more recent deposits. This point, however, can be satisfactorily determined only by examination of the stratigraphical relations of the various formations. My judgment is based upon the relations of the various formations in the few sections presenting several of the formations in succession.

The descriptions in Dr. Penrose's Report (Ann. Rept., 1890, vol. i) stratigraphy of Independence county led me to infer a similar explanation of the facts there; but evidence was not then at hand to disprove the reference of the red limestones, lying above the interval-accumulations, to the Silurian limestone. If Dr. Penrose was correct in his reference of the upper limestone, in the section of the O'Flynn mine (p. 231, fig. 14), to the St. Clair limestone, it is difficult to discover any relationship between the Sylamore sandstone and the manganese deposit which would be included in the midst of that limestone. Among the specimens sent in by Mr. Hopkins, there is no evidence of the Silurian limestone at the O'Flynn mine, but there does appear evidence of a deposit similar to the Sylamore sandstone in connection with the so-called manganese bed. The relationship existing between the Sylamore sandstone, which is the phosphate-bearing rock of this region, and the manganese deposits described in the Batesville region, is not yet clear.

As Dr. Branner has suggested in a latter discussion of the subject,* it would appear that the Sylamore sandstone, and the manganese deposits, are confused in some of the sections. Whether the reason for this is the wearing down of the Silurian series, so that the Devonian interval deposits were laid upon the surface of the manganese deposits (the Cason shale), or whether they have been let down by the solution of an originally intervening limestone, it is difficult to determine with the evidence now before us.

There seems to be good evidence to suppose that they are not of the same geological age. Further study of the whole problem of the deposits filling the Devonian interval in the south† has led to the conclusion that, however much erosion of the underlying Silurian formation took place, the sediments of black mud forming the shale did not begin till after the beginning of the Devonian era. The association of the fragments of thick bones of large fish with the worn Sylamore sandstone, is observed on the eastern margin of the Cincinnati plateau in Kentucky. So far as our knowledge of the range of species goes, these fish were not living till the early part of the Devonian era. The black shale following such worn material suggests a sinking of the particular region, and when the shale and the worn fragments and nodules alternate, as they appear to do in central Tennessee, it may be taken as evidence of the continuous, shallow condition of the region, which was at that time the southern extension of the Cincinnati plateau.

Note.—While preparing this report for publication, I have seen vol. iii, Part II of the Minnesota Report,‡ and notice a remark which suggests the extension of this peculiar interval deposit as far north as Minnesota. Describing the section of the rocks at Prosser's ravine near Wykoff, Fillmore County, the authors state that "Succeeding the foregoing bed [which was of uncertain age, of 6 feet thickness, regarded as Upper Silurian, the passage of which lithologically from the Richmond group (upper Cincinnati group) is described as exceedingly gradual] and followed with not very strong evidence of unconformity by Devonian strata, is a sandstone four feet thick, which here and there contains large numbers of small quartz pebbles, varying between 1 and 10^{mm} in diameter. This sandstone we assume to belong to the Oriskany of New York" (p. cv). The evidence of elevation and erosion, prior to the deposit of this so-called Oriskany, is found in the absence of the formations immediately preceding the Devonian formation in complete sections. The beginning of permanent sedimentation with well-worn pebbles is what should be expected, as the land was depressed, whatever the time at which it took place. A similar thin layer of much worn pebbles and sand, separates the magnesian limestones (Ordovician) from the underlying gneiss, at a section on the southern slopes of the Adirondack at Little Falls, New York. It is followed by black mud shale with Lingulas, and then the regular magnesian limestone of considerable thickness. So other cases might be cited, the age of the beginning of the new sedimentation being determined by the first fossils above the abrupt change, and the unconformity may not be indicated by conspicuous modification of the plane of sedimentation. We should less expect real unconformity in the central part of a continental mass, as in the Mississippi valley region, than on the borders where the folding and faulting has been chiefly concentrated.

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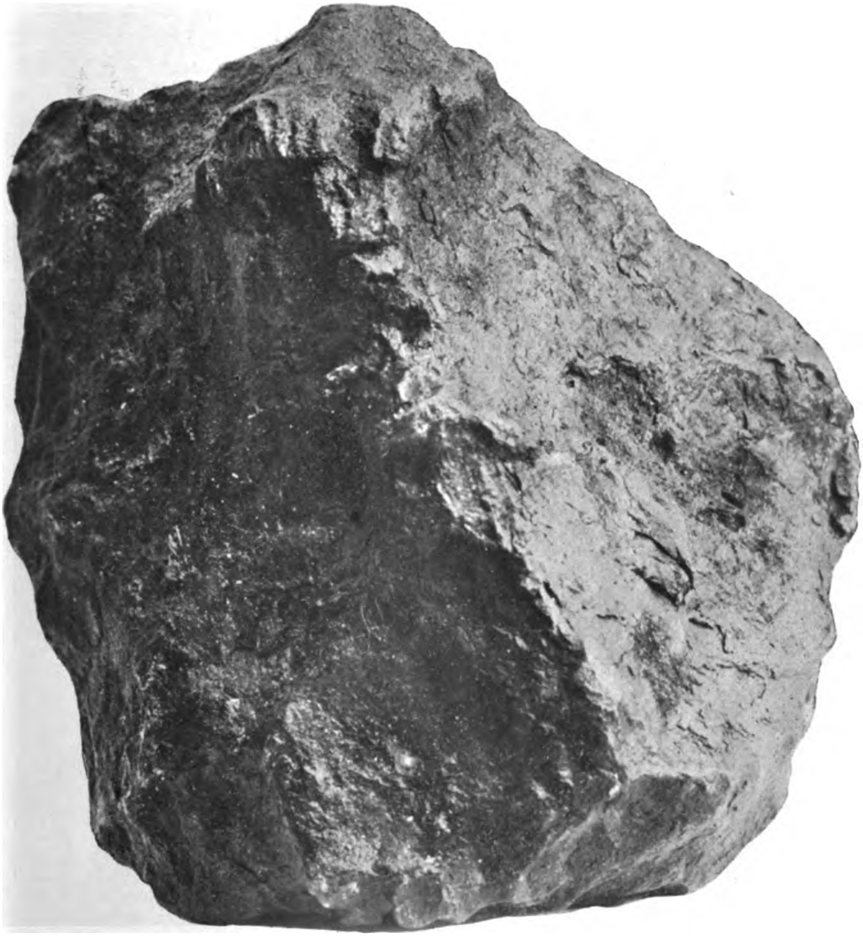
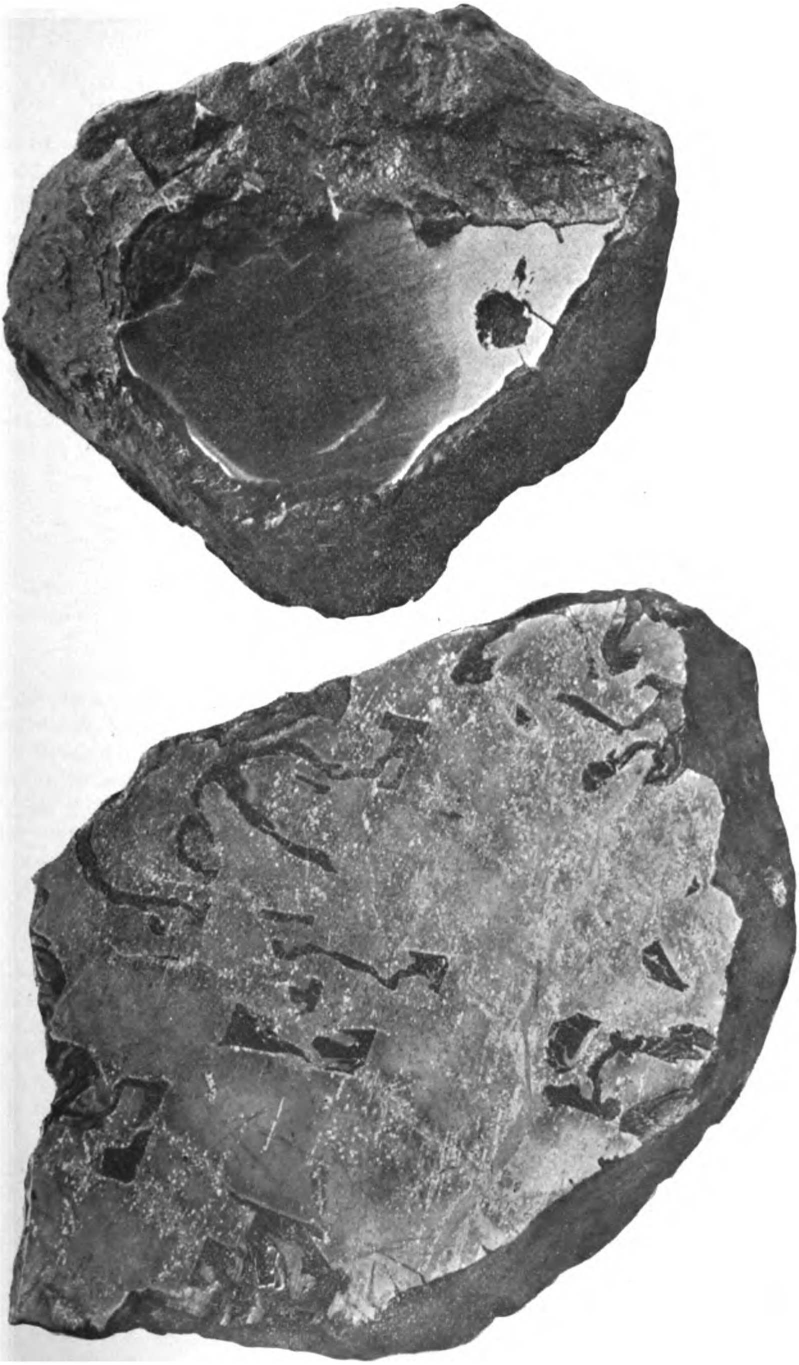
* See the Phosphate Deposits of Arkansas, by J. C. Branner, Am. Inst. Min., Eng., 1896.

† See the southern Devonian.

‡ Geology of Minnesota, vol. iii, Part II, of the final report. Paleontology, 1897, p. cv.



Meteoric Iron found near the Tombigbee River, Ala. No. 1 Mass. Scale ⅔.



Meteoric Iron found near the Tombigbee River, Ala. Nos. 5 and 3 Masses. Scale ¾.

Art. XVI.—*Note on a New Meteoric Iron found near the Tombigbee River, in Choctaw and Sumter Counties, Alabama, U. S. A.;* by Warren M. Foote. With Plates II and III.

In March last, the firm of Dr. A. E. Foote, Philadelphia, Pa., received from Mr. Elbert J. Brower, Keewanee, Miss., a small sample of iron which bore evidences of meteoric origin. A further correspondence resulted in the purchase by this firm, through Mr. Brower, of six masses of meteoric iron, constituting so far as known, an entire "fall." Later a lengthy but unsuccessful search and inquiry was made in the vicinity for other pieces which might have fallen.

Nothing whatever is known in that section concerning the actual fall; therefore the collection of data made by Mr. Brower was limited to securing statements from the finders and the owners of property on which the masses fell. These statements, taken in the presence of witnesses last June, are offered as a true history under Mr. Brower's affidavit, and after arrangement and elimination of irrelevant matter by the writer, are here briefly outlined.

The external appearance of the specimens is best understood by reference to Plate II, made from a photograph of the largest mass found. It resembles the usual type of siderites, the characteristic depressions and oxidization being well shown. In parts the latter assumes the form of limonite, and what is apparently an earthy hematite. The disintegration of the iron is rather marked, being accompanied by oxidization and the deliquescence of a reddish-brown fluid, lawrencite. This latter feature was remarked by the finders, when the specimens were left in the rain. The one-third decrease in weight, reported as occurring since the largest mass was found twenty-one years ago, is further evidence of instability, in the absence of any precautions for preservation.

Internal Structure.—The smaller mass (No. 5), shown in Plate III, exhibits a pronounced cleavage in one corner from which a sample, already referred to, was broken. This cleavage is probably not due to any uniform crystalline structure, but to the thin plates of a pyritiferous mineral, which are irregularly scattered through the mass. The edges of several of these plates appear as sharp lines, resembling scratches on the polished surface, their true nature becoming evident on etching. The iron is soft and takes a brilliant polish. On etching No. 5 with dilute nitric acid a cubic crystallization was disclosed by the development of minute Widmanstätten figures, whose form could only be observed with the aid of a lens. The lines were exceedingly fine and crossed at varying angles. A notable difference is seen between the above and the markings on an etched face of one-half of No. 3 specimen, shown in the lower part of Plate III. In the latter occurs a bright bronze-gray mineral which proved after qualitative analysis to be schreibersite. It is strongly magnetic and contains considerable amounts of iron, nickel and phosphorus. This assumes the curious and novel form of large graphic characters, some of the curved branching figures terminating in angular crystallizations. While Widmanstätten figures are absent, the plessite exhibits a beautiful phenomenon, suggestive of a metallic sunstone. It presents a glistening, frosted effect, which changes with the light, due to the arrangement of tin-white flakes or fissures of the metal. Other portions of the etched plessite remain perfectly smooth from the lack of crystallization. The illustration poorly represents the oddity and beauty of the specimen, yet indicates the unique features, which establish for it a separate position among the siderites.

The Composition, as shown by an analysis made by Mr. J. Edward Whitfield, on about four grams of the clean metallic portion from No. 5, is as follows:

	Per cent.
Iron	95·02
Nickel	4·11
Cobalt	0·40
Phosphorus	0·324
Carbon	0·161
Sulphur	trace.
	100·015

History of six masses, having a total weight of 43,795 grams (96 lbs. 9 oz.).

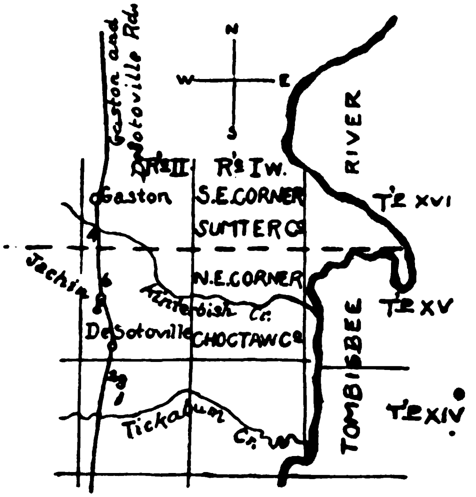
No. 1. Weight 15,019 grams. See Plate II. Said to have weighed 22,200 grams when found about 1878. Is now to all appearances a complete mass. Found in presence of J. P. Smith and C. L. Smith, by R. Y. Smith on the Pleas May property, 150 yards south of the Meridian and Tomkinsville road, on the west slope of a hill, next an uprooted pine tree, which probably dislodged the specimen from the spot in which it was buried by the fall. Location, S. W. quarter of Sec. 9, Range 2 west, Township 14, Choctaw Co.

No. 2. Weight 11,976 grams. Irregularly rounded mass. Found about 1886 by R. Y. Smith in plowing on land of G. D. Smith, on the west slope of a hill situated in the S. E. quarter, Sec. 5, Range 2 west, Township 14, Choctaw Co.

No. 3. Weight 9,215 grams. Irregularly rounded piece. Found about 1886 by William Howington on land of G. D. Smith on top of a hill in S.W. quarter of Sec. 4, Range 2 west, Township 14, Choctaw Co. (about one-quarter mile south of No. 2).

No. 4. Weight 3,568 grams. Flat, oblong piece, showing depressions. Found by Henry Wilkerson on property of George Bennet, at the side of a ten foot cut in the Gaston and DeSotoville road, which there traverses the east side of a hill. Location, about 2 miles south of Gaston in the N. E. corner of Sec. 31, Range 2 west, Township 16, Sumter Co. This specimen, like No. 1, was buried at some depth by the fall, and was unearthed by the wearing down of the public road at this point.

No. 5. Weight 3,260 grams. Egg-shaped mass shown in upper half of Plate III. Plowed up by W. C. Moore on land of R. L. Moore, situated in the N. E. corner of Sec. 19, Range 2 west, Township 15, Choctaw Co. Found about 400 yards west of the Gaston and DeSotoville road, on west slope of a rocky hill, one-quarter mile S. W. of Jachin.



The numerals show the location in which the masses enumerated in the text were found.

No. 6. Present weight 757 grams. Flat oval. Found about 1859 or earlier by Ben Johnson on land of M. E. Grace. Presented to D. F. Alford, who made a horse-shoe nail from a portion of it (original weight not known). Found about one mile north of Jachin, just east of Gaston and DeSotoville road, in S.E. corner of Sec. 7, Range 2 west, Township 15, Choctaw Co.

It will be seen from the accompanying map that the masses were found in almost a straight line N. and S. and along a nine-mile stretch of the public road. As in the case of the Coahuila, Mexico, irons (J. Lawrence Smith), which were found in a line N.E. to S.W., the smaller pieces falling first, one cannot avoid applying such a theory to the present find. The main mass moving from north to south, parted during its flight and the fragments continued in the same general direction, the smaller ones falling first. In support of this theory are the facts: at the northernmost point of the line was found a mass of about 3½ k.; three miles to the south, a mass of which only a portion (¾ k.) was preserved; one mile south of that, a 3¼ k. piece; four miles farther south, two were found ¼ mile apart, weighing respectively 12 k. and 9 k.; finally one mile beyond, at the south end of the line, the largest, weighing about 15 k. In all probability, the decrease in weight, due to exposure after reaching the earth, was relatively about the same for each. Since the fall occurred in two counties, near three small villages, it may be conveniently designated by the name of the nearest geographical feature, the "*Tombigbee River*," in the western watershed of which the find was made.

The two other iron meteorites, which are near enough geographically to the "Tombigbee River" to suggest relationship, are "Claiborne," about 60 miles to the S.E. in Clarke Co., Ala., and "Oktibbeha Co.," about 60 miles west in Mississippi, That they are not of the same fall is shown by their widely dissimilar compositions, the first containing 95·02 per cent iron and 4·11 per cent nickel; the second, 66·56 per cent iron and 24·74 per cent nickel; the third, 37·69 per cent iron and 59·69 per cent nickel.

Philadelphia, July 10, 1899.

ART. XVII.—*On the Orthoclase Crystals from Shinano, Japan;* by C. IWASAKI, Kyoto, Japan.

THE crystals of orthoclase described in this paper were obtained by me from Mr. K. Okubo, a schoolmaster in Nozawa, Minamisakugôri, Shinano, who has had the kindness to place in my hands some fifty specimens from a locality recently discovered by him in Môraiyama of the same district.

In the western margin of the geological block known as the Chichibu region, where the geology of the Japanese Paleozoic formation has been studied and the name "Chichibu Group" has been given, there are several occurrences of quartz-diorite as dikes. Through some of them, there are mineral veins a foot in width formed, and the orthoclase crystals are found in them mixed with quartz.

The orthoclase crystals are all elongated in the direction of the clino-axis; one end being always broken. They are of moderate size, and measure one and a half inches in the longest diameter. They are brownish white in color, often with thin coating of the brown earth. The clinopinacoid (010) is comparatively clean and lustrous, and striations parallel to the vertical axis are seen on it. The basal face (001) is usually discolored and the cleavage along it is most perfect. All faces are so dull that the facial angles can only be measured approximately by the contact goniometer. Six crystal faces, (010), (001), (110), (130), $(\bar{1}01)$, $\bar{2}01)$, have been identified.

The crystals are nearly always twinned after the Baveno type but of different types. They may be divided into the four classes mentioned below.

(1) *Simple crystals* (fig. 1).—The simple crystals are most rarely met with. Only two were found among fifty specimens, and, even in them, the twinning traces are seen in their margin. The crystal habitus is as usual.

(2) *Twin crystals of the Baveno type* (figs. 2 and 3).—All crystals are drawn in the orthographic projection toward the clino axis. Fig. 1. Simple crystal; figs. 2, 3, twin crystals of the Baveno type (110) and (130) are more developed in 3. Figs. 4–8, Baveno trillings: 4, normal case; in 5 and 6, the groove between A and C, proceeds into B; in 7 the prism is absent; in 8, the faces are unequally developed on both sides of the groove. Fig. 9. Baveno fourling. The simple crystals are frequently twinned after the Baveno type, a diagonally truncated prism being the result. Among the terminal faces (110) plays the most important rôle, $(\bar{1}01)$, $(\bar{2}01)$ and sometimes (130) being only seen in a corner or on the edges, but rarely $(\bar{1}01)$ and $(\bar{2}01)$ are highly developed and (110) is depressed in one side as shown in fig. 3.

III. *Baveno Trillings.*—The crystals are most frequently twinned after the Baveno type in the cyclical order, and form the same individual as so-called "Drilling" of Naumann.* If these three individuals be noted as A, B, and C (fig. 4), the prismatic faces of A and C are in juxtaposition forming a groove between these two faces. The most simple case of this type is shown in fig. 4. Often the groove proceeds into B, and two faces of the prism of the same individuals make a reëntrant angle $(\bar{2}01)$ sometimes $(\bar{1}01)$ being divided into two areas. The development of the crystal faces on both sides of the groove commonly takes place to the same extent. But sometimes they are unequal as shown in fig. 8.

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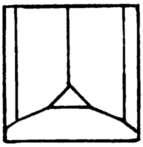

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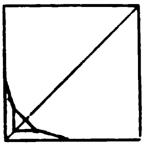

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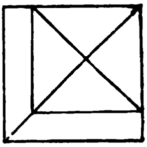

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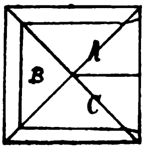

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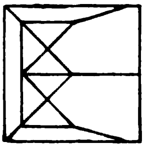

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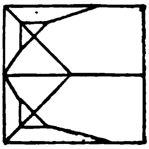

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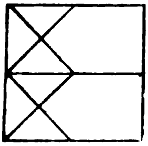

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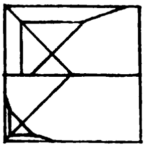

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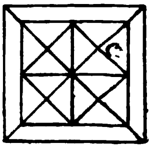

IV. *Baveno Fourling* (fig. 9).—Finally four crystals are twinned in the cyclical order, forming the so-called "Vierling" of Naumann, eight faces of the prism of the four individuals meeting each other, forming the adjacent faces, and at the same time making a hollow pit in the center of the top of the longer diameter of the crystal. The four faces parallel, the longer diameter consists of four basal faces, while the clinopinacoids are wholly hidden. Hessenberg† describes such crystals from Orfano of Italy. The orthoclase here described is simpler than his, and does not form the "4 tower in the four corners" described by him, but only the hollow pit in the center.

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* Hintze, Handbuch der Mineralogie, ii, 1341.

† Min. Not., 1867, iv, 45, 183, v, 15.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the two new Radio-actino Elements, Polonium and Radium.*—Early in 1898* Mme. **SKLODOWSKA CURIE** pointed out the fact that certain uranium and thorium minerals, pitchblende, torbernite and autunite, emitted Becquerel rays more actively than even uranium or thorium, and suggested the presence in these minerals of a new substance. Later, in conjunction with her husband, P. **CURIE**, she published the method followed in the chemical examination of pitchblende, which resulted in the isolation of the new active substance. The mineral was dissolved in acid and the solution treated with hydrogen sulphide. The uranium and thorium remained in solution and the precipitate contained, besides lead, bismuth, copper, arsenic and antimony, the sulphide of the new material, which being insoluble in ammonium sulphide, was thus separated from arsenic and antimony. The insoluble sulphides were treated with nitric acid, and a partial separation from lead effected by sulphuric acid. On exhausting the lead sulphate with dilute sulphuric acid, the active substance together with copper and bismuth were obtained in solution. On adding ammonia, the new body and the bismuth were thrown down, thus separating them from copper. Complete separation from bismuth was not obtained; though by heating the mixed sulphides to 700°, the greater volatility of the new sulphide enabled them to get a product which was 400 times more active than uranium. Believing this new substance, resembling bismuth so closely, to contain a new element, the authors gave it the name *polonium* from Poland, Mme. Curie's native country. For this discovery the Academy of Sciences awarded the Gegner prize to Mme. Curie.

In continuing their observations upon pitchblende, M. and Mme. **CURIE**, in association with **BEMONT**, detected a second radioactive substance in this mineral, having entirely different chemical properties. It resembles barium closely, not being precipitated either by hydrogen sulphide, by ammonium sulphide or by ammonia. Its sulphate is insoluble in water and in acids, its carbonate is insoluble in water and its chloride, while very soluble in water, is insoluble in concentrated hydrogen chloride and in alcohol. The product obtained gave the barium spectrum, showing that the body consisted mainly of this substance. But barium is not radio-active; and since radio-activity seems to be an atomic property, the authors attribute it to a new element associated with the barium. The first portions obtained were 60 times more active than uranium. By a series of fractional precipitations of the chloride with alcohol a final product was obtained 900 times more active. The spectrum examined by Demarçay gave a characteristic line of wave-length 3814·8. In consequence the authors propose for the new element the name *radium.* Like uranium and thorium, polonium and radium act photographically on sensitive plates and render the surrounding air a conductor of electricity; though they are far more effective. An exposure of half a minute gives with the latter an effect equal to that of several hours with the former.—*C. R.*, cxxvii, 175–178, July, 1898; 1215–1217, 1218, December, 1898. G. F. B.

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* C. R., cxxvi, 1101–1103.

2. *On Liquid Hydrogen.*—The Centenary of the Royal Institution of Great Britain was fittingly celebrated on the 7th of June by an admirable lecture, by Professor **Dewar**, on Liquid Hydrogen as an instrument of research. He had upon the lecture table a liter of this substance, preserved in triple vessels containing liquid air surrounding the hydrogen. It is transparent and has a well-defined meniscus; and when the cotton plug closing the tube is removed, the entering air is at once frozen to a solid and falls to the bottom like a precipitate. A small wad of cotton on a glass rod dipped into it and lighted gives the well-known hydrogen flame. A small cork ball sinks at once in liquid hydrogen. A solid immersed in it for a few seconds becomes so cold that it liquefies the surrounding air on withdrawal, which runs off in drops; while a tube of liquid air is at once solidified in it. An empty bulb placed in the space above the liquid hydrogen is at once filled with solid air. Oxygen also becomes solid and when lifted out is seen gradually to melt. Though not itself magnetic the oxygen liquified from the air on a cotton plug cooled in hydrogen is drawn to the magnet. The real temperature of the liquid hydrogen he had found to be 21° absolute, a hydrogen gas thermometer and a german-silver resistance thermometer giving the same reading. Very perfect vacua were obtained by cooling tubes containing air in liquid hydrogen; so perfect indeed that no electric discharge could pass through them. Comparative contraction of a hydrogen thermometer placed in liquid air and in liquid hydrogen showed that in the latter was four times as great as in the former. To reach the absolute zero even approximately two more steps must be made substantially as great as the one now made between liquid nitrogen and liquid hydrogen.

3. *On Ozomolybdates.*—By digesting a molybdate of one of the alkali metals with hydrogen peroxide, **Muthmann** and **Nagel** have found it possible to add oxygen to it to the extent of one atom of oxygen or less per atom of molybdenum. The compounds thus formed, however, cannot properly be regarded as salts of permolybdic acid, since they lose oxygen readily, reducing silver oxide and permanganic acid with evolution of oxygen. The apparent addition of an atom of oxygen therefore seems really to be a replacement of one atom of oxygen by two linked together as in hydrogen peroxide or ozone. Hence the name ozomolybdates given by the authors to this class of compounds.

Ozomolybdic acid, $H_2MoO_6 . (H_2O)_x (x = 1\frac{1}{2} ?)$ was obtained by digesting molybdic oxide with a 25 per cent solution of hydrogen peroxide, finally on the water bath, filtering and concentrating the filtrate under reduced pressure. It is amorphous, and orange-red in color; and besides reducing permanganate, silver oxide and hypochlorites, it liberates the halogens from their hydrogen compounds. Rubidium and cæsium ozomolybdates, prepared similarly, are described. They are crystallized and vary in color from yellow through yellowish red to orange-red.—*Ber. Berl. Chem. Ges.*, xxxi, 1836–1844, July, 1898. G. F. B.

4. *On the Action of Charcoal in the Purification of Spirit.*—An exhaustive investigation has been made by GLASENAPP as to the part which charcoal plays in the purification of spirit. From the results obtained it appears that charcoal does not absorb fusel oil but acts chemically through the oxygen condensed in its pores. The fusel oil is oxidized to ketones and aldehydes and the latter partly to acids, which then to some extent act on the alcohols forming esters with them, these various products giving a characteristic odor and taste. Since these bodies are soluble in chloroform, they would, unless previously removed, be counted as fusel oil in applying Rose's well known process of analysis. Charcoal itself absorbs these products to a large extent; so that in fact spirit filtered through it often shows less aldehydes than the unfiltered sample. On heating the charcoal afterward to regenerate it, a distillate is obtained which is rich in ethers and aldehydes, though it does not contain more fusel oil than the original liquor. The author advises thoroughly impregnating the charcoal with oxygen by heating the regenerated material in a current of dry air. He suggests that by filtering at a somewhat higher temperature, a better product might be obtained.—*Zeitschr. angw. Chem.*, 617–621, 1898; *J. Chem. Soc.*, lxxiv, 616, December, 1898. G. F. B.

5. *On the Constitution of the Simplest Proteids.*—According to the earlier experiments of KOSSEL, the molecule of the complicated proteids contains an atom-complex similar to the protamine group. Hence more accurate chemical knowledge of the protamines should give us an insight into the constitution of the albumin molecule. The author has therefore studied more carefully the three following protamines: Sturine from the spermatozoa of the sturgeon, salmine from that of the salmon, and clupeine from herring sperm. The protamine sulphates were prepared according to a method already described, and freed from the last traces of nucleic acid. On adding alcohol to the evaporated solution, the protamine sulphate separates. Clupeine sulphate dried at 110°–120° has the formula $C_{30}H_{57}N_{17}O_6(H_2SO_4)_2$. It is a white powder, easily soluble in warm water. On cooling the solution a colorless highly refractive oil separates, which like the clupeine sulphate itself is lævo-rotatory. Clupeine has a strongly alkaline reaction. Salmine sulphate probably has the formula $C_{30}H_{57}N_{17}O_7(H_2SO_4)_2$, and differs from clupeine sulphate only in

having H_2O more ; a difference which the author attributes to the mode of drying. As they have the same solubility, optical activity and refractive index, they are probably identical. Sturine is more soluble than the others, and its sulphate, which is an oil, has the probable formula $(C_{36}H_{69}N_{19}O_7)_4 . (H_2SO_4)_{11}$. By hydrolysis, protones or peptones of the protamines are first produced. Then the hexon bases appear, histidine, arginine and lysine. Clupeine gives a molecule each of histidine and lysine and three of arginine, while the sturine gives one molecule of histidine, two of lysine and three of arginine. Since proteids as well as protomines yield these hexon bases, it is reasonable to suppose that the albumin molecule contains a protamine complex. To this are attached other groups which yield the amido acids of the fatty series, a third group gives tyrosine, and a fourth the decomposition products containing sulphur.—*Zeitschr. physiol. Chem.* xxv, 165–189, 1898. G. F. B.

6. *On Hæmochromogen.*—Hæmochromogen has been prepared by VON ZEYNEK by reducing an ammoniacal alcoholic solution of hæmatin with hydrazine hydrate in an apparatus from which both oxygen and moisture could be excluded. From the solution it is precipitated by a mixture of alcohol and ether as a red amorphous mass resembling red phosphorus. As a mean of five analyses, the following numbers were obtained : C 63.83, H 5.66, Fe 9.25, N 11.48, O 9.78. Since the formula of hæmatin itself is doubtful, these numbers cannot lead to any definite conclusion as to the constitution of hæmochromogen. When its solution in ammonia is neutralized with acetic acid, a voluminous brownish-red precipitate is thrown down which contains iron, and on redissolving it in ammonia shows the characteristic spectrum of hæmochromogen. This substance appears to be the only product of the action of hydrazine hydrate on hæmatin; while with oxyhæmoglobin and methæmoglobin the action goes farther, producing hæmoglobin, then hæmochromogen ; the solution becoming soon decolorized.—*Zeitschr. Physiol. Chem.*, xxv, 492–506, 1898. G. F. B.

7. *Geschichte der Physikalischen Experimentierkunst.* Von Dr. E. GERLAND und Dr. F. TRAUMÜLLER; pp. 442. Leipzig, 1899. (Wilhelm Engelmann.)—This volume occupies quite a new field. There have been histories of physics which have given an account of the development of physical laws and principles, but here we have the course of experiment detailed from the earliest time down to the first half of the present century. Some of the opening pages are given to the Egyptians and their work in metallurgy, and then follows an account of the discoveries of the Greeks and Romans, the Byzantines and Arabians until we reach the scientific awakening of the sixteenth century. From here on, one familiar subject after another is developed, and it is highly interesting to see how many experiments and illustrations which still live in modern text-books had their origin several hundred years ago. The figures introduced are numerous and well chosen

from the original sources and add much to the general interest of the volume, even when not absolutely necessary for the explanation of the subject. We have, for example, the frog's legs of Galvani's classical experiment; the Magdeburg hemispheres, with the experimenter at work, and again with the horses attached attempting to pull them apart, and many others.

II. GEOLOGY AND MINERALOGY.

1. *The Terminology of Vertebral Centra;* by G. R. WIELAND (communicated).—In the early nomenclature of palæontology vertebræ received no definite names based on the termination of their centra in flat, concave, convex, or saddle-shaped surfaces. Instead descriptive sentences were used. Thus, Cuvier states that the centra of crocodilian vertebræ are "*concave en avant et convex au dernière.*"

Later, Owen applied to the principal types of centra the names now in common use. It may be said of these terms that they are expressive and euphonious, but do not form a connected system, though this is suggested by the correspondence between lenses and the types of centra.

In the following table an attempt is made to unify Owen's names, and extend them into a completed system:

	Vertebræ.			
LENSES.	OWEN.	SYSTEMATIZED.	DERIVATION.	EXAMPLES.
(Plane)	Amphiplatyan	Platyan	Gr. πλατύς, flat	*Plesiosaurs.*
Biconvex	Biconvex	Cyrtean	Gr. κυρτὸς, convex	First caudal of Sauropodous *Dinosaurs.*
Biconcave	Amphicœlian	Cœlian	Gr. κοῖλος, concavity	*Icthyosaurs.*
Plano-convex	-------------	Platycyrtean Cyrtoplatyan	*ad seriatim.*	
Plano-concave	Platycœlian	Platycœlian	"	*Cardiodon.*
Concave-plane	-------------	Cœloplatyan	"	First sacral of existing *Crocodilia.*
Concavo-convex	Procœlian	Cœlocyrtean	"	*Pythonomorphs.*
Convexo-concave	Opisthocœlian	Cyrtocœlian	"	*Streptospondylus.*
(Saddle)	-------------	Ephippic Platyphippic, etc., etc.	Gr. ἐφίππιον, saddle *ad seriatim.*	*Aves.*

The proposed changes in these adjectives require little further explanation. In describing a given centrum the anterior face is always taken first, and the centra further described adjectively when necessary, as at present. For example, the cervical vertebræ of *Chelydra serpentina* would be described as follows:—

The third cervical is cyrtocœlian, the fourth cyrtean, the fifth and sixth are cœlocyrtean, with the posterior, or cyrteal, face of the latter nearly flat and very broad; the seventh is platyan with very broad faces, the hinder being slightly convex, while the eighth like the fifth and sixth is cœlocyrtean, but differs from the others in the expansion of its neural spine and the arching backward of its postzygapophyses over the convex prezygapophyses of the first dorsal upon which the former play backward and forward. (Cf. Huxley's Anatomy of Vertebrated Animals, London, 1871, p. 171.)

2. *Cycadean Monœcism;* by G. R. WIELAND (communicated).—The living and fossil Cycads, so far as hitherto observed, are *diœcious.* Hence, it is important to note that certain Mesozoic species from the Black Hills, now in the Yale Museum, and referred to the genus *Cycadeoidea* as commonly employed, have been recently found to be *monœcious.* These possess essentially the types of male and female fructification described by the writer in his preliminary papers on a Study of American Fossil Cycads, Parts I-III (this Journal, March-May, 1899).

The species there recorded as diœcious are probably of that nature. All the evidence at present available strongly points to the diœcism of *Cycadeoidea Colei, C. turrita, C. Wielandi, C. ingens,* etc. On the contrary, other species in full fruit recently studied bear typical male and female fructifications on the same trunk. Of these may be mentioned *Cycadeoidea Minnekahtensis, C. Wellsi, C. Dacotensis,* etc. The limits of this monœcism and diœcism can not be determined without abundant material and a long series of observations. Fortunately, the richness of the Yale collection will go far towards solving this problem.

The condition of monœcism in Cycads thus places this group of plants one step nearer the conifers. Nevertheless, in view of the fact that the Cycads of the Black Hills Jurassic were so proliferous in habit, it is not surprising that monœcious forms should occur, especially when the great variability of gymnosperms in this respect is considered. That these Mesozoic species, so closely related as to have been included in a single genus, should be found to possess both kinds of unisexuality, however, adds great interest to the *Cycadeæ,* as well as an important chapter to the knowledge of sexual characters in plants.

3. *Sur Stereosternum tumidum, Cope;* by H. B. GEINITZ. Ann. Soc. géol. de Belg., xxv, 8 pages, and one large double-page plate, 1899.—Dr. Geinitz reproduces, by some photographic process, the forms of two fine specimens of this species obtained from the ?Permian beds of São Paulo (Brazil), and now in the Royal Museum of Mineralogy at Dresden. In the text, the formations and known fossil associates, as well as the biological characters of the specimens, are defined. Though believed to be Permian, the exact age of the beds is not established beyond controversy.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XVIII.—*On the Gas Thermometer at High Temperatures;*

by LUDWIG HOLBORN and ARTHUR L. DAY.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany.]

THE high temperature measurements which have been undertaken by various observers with the gas thermometer are not yet free from considerable disagreements.

Violle[*] determined the melting point of gold to be 1035° C., a value which he afterward increased to 1045°; Barus's[†] determination for the U. S. Coast and Geological Survey was 1092°, and one of the authors of this paper has published with W. Wien[‡] the value 1072°.

In all three cases the melting point was not directly determined with the gas thermometer. Violle ascertained first the specific heat of platinum with the gas thermometer and then by calorimetric methods the melting point of gold, while in the last two instances a thermo-element was compared with the gas thermometer, after which it was used for the actual melting point determination.

Neither the indirect method, nor the inherent experimental difficulties which stand in the way of all investigation at high temperatures, sufficiently explain the differences mentioned. Especially recently, the relative measurement of high temperatures electrically has become less difficult and more accurate, as a consequence of which the variations of the temperature scales of different observers among themselves is the more unpleasantly conspicuous and disturbing.

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[*] Violle, C. R., lxxxix, 702, 1889.

[†] Barus, Bull. U. S. Geolog. Survey, 54, 1889; Proc. Am. Acad., xxvii, 100, 1892.

[‡] Holborn & Wien, Wied. Ann., xlvii, 107, 1892, and lvi, 360, 1895.

With the idea that these differences were, in part at least, due to the construction and handling of the gas thermometer itself, the first step toward the establishment of a new scale was thought to lie in the direction of an investigation of the principal instrument involved. The results of such an investigation are contained in this paper.

There is no doubt that the principal difficulty lies immediately at hand, viz., in providing a suitable bulb to hold the expanding gas. Since Deville and Troost* proved that hydrogen would pass through the walls of a platinum bulb at high temperatures, observers in general have turned to porcelain as the only practicable material, although the results obtained by Becquerel† with the Pouillet platinum bulbs compare by no means so unfavorably with the determinations above quoted, and the discrepancy between the Becquerel values and those obtained at about the same time by Deville and Troost was sufficiently explained by the dissociation of the gas (iodine vapor) chosen for the observations.

Among recent observers Violle, following the precedent of Deville and Troost, used porcelain bulbs glazed inside and out, while Barus, as well as Holborn and Wien, adopted those glazed only on the outside. The limits of usefulness of the bulbs with inside glazing must be reached when the glaze begins to melt, i. e. at about 1100°, otherwise vaporization is certainly to be feared. The porcelain walls themselves hold out longer, in fact the bulbs without inside glazing used by Holborn and Wien were used up to 1450°, but of course at such a temperature the pressure inside and out must be approximately the same, that the already soft walls may not be deformed thereby. At these temperatures porcelain bulbs only remain air-tight by virtue of the glazing—unglazed porcelain is not air-tight.

Brief review of investigation.—Our experiments up to a temperature of 550° were made with bulbs of Jena "borosilicate" glass No. 59^{III} and hydrogen as the expanding gas; then porcelain bulbs glazed inside and out were tried up to 1100°, first with hydrogen and afterwards with atmospheric nitrogen; next porcelain bulbs with outside glazing only were heated above 1200° with nitrogen; and finally a platin-iridium bulb, which when heated electrically proved entirely free from the disadvantages of porcelain, was used with chemically pure nitrogen over the whole range of temperature up to 1300°.

Toward the close of the observations we also had the advantage of entirely new manometric apparatus especially adapted to our purposes, in which the volume of unheated gas was much reduced and the use of low pressures in the bulb made possible.

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* Deville and Troost, C. R., lvi, 977, 1863.

† E. Becquerel, Ann. de Chim. et de Phys., III, lxviii, 49, 1862.

The glass bulb proved to be exceedingly well adapted to the purpose up to 500°, showing no appreciable change in the zero point after being repeatedly heated, while with porcelain, even when nitrogen was afterward substituted for the hydrogen, the zero point did not remain constant, but rose slightly after each heating, denoting an *increase* in the gas pressure. Furthermore, the expansion-coefficient of the gas between 0° and 100° often showed changes larger than could be accounted for by the errors in observation.

Such changes, even when they remain small and the temperatures measured with the bulbs agree fairly among themselves, are persistent and disturbing factors in the measurement of high temperatures.

Another misfortune arises from the fact that porcelain is not a definite chemical compound, and bulbs from different sources may behave quite differently; even bulbs ordered at different times from the same source have the same unfortunate tendency.

These, with the above mentioned fact that bulbs glazed on the inside do not admit of use above 1100° at all, and the unglazed ones only with difficulty and under conditions of greatly diminished sensitiveness, led us to direct our attention once more to metallic bulbs and to investigate the behavior of a platin-iridium cylinder under the above conditions.

From the results thus far obtained we do not hesitate to say that in our opinion such a bulb is certainly to be preferred to porcelain for the higher temperatures.

This bulb filled with nitrogen and heated to 1300° showed a constancy of the zero point and coefficient of gas expansion such as we have only been able to obtain from glass bulbs at comparatively low temperatures. This result is, however, in no small degree dependent upon arrangements for heating by electricity and the consequent freedom from all sorts of combustion products, which if present, as we observed repeatedly, pass rapidly through the bulb wall, even against an excess pressure within.

For comparison of the gas-thermometer readings among themselves, they were referred to a platinum, platin-rhodium thermo-element observed simultaneously.

For temperatures up to 750° bulb and thermo-element were dipped into a bath of nitre and in the vicinity of 900° a zinc vapor bath was tried. As no bath is yet available for temperatures above that point which does not seriously injure the walls of the bulb, the remaining temperatures were attained electrically by heating a coil of nickel wire wound upon a thin tube of porcelain or clay. The last proved the most convenient of all both for producing and maintaining constant any temperature within the range of the present series.

1. Gas Thermometer.

For the experiments with the gas thermometer the "constant volume" principle only was used, in order that a nearly uniform sensitiveness might be maintained throughout the entire range of temperatures. As manometer we had at first at our disposal an apparatus constructed by Fuess (Berlin) and used and described by Wiebe and Böttcher,* a few necessary changes being made to adapt it to our purposes. Afterward a second similar instrument from the same workshop was used, a drawing of which (fig. 1) is here given.

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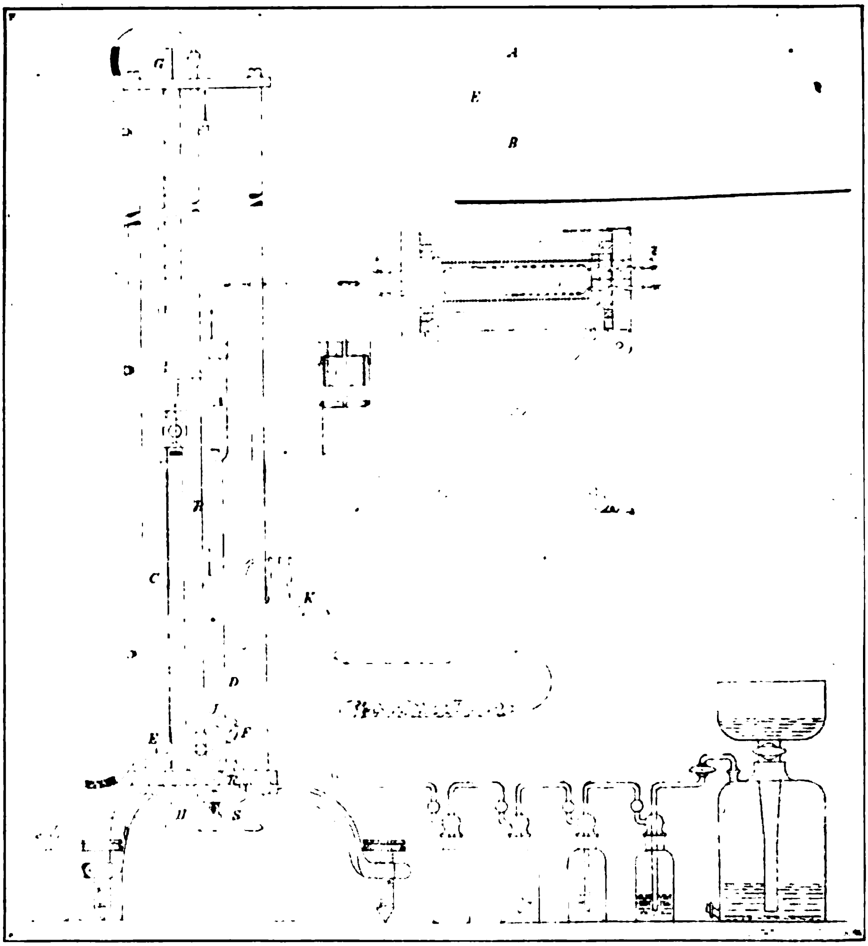

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* Wiebe and Böttcher, Zeitschr. für Instr., x, 18, 1890.

The manometer consists of two upright tubes, A and B, which dip into a closed iron reservoir, R, from which mercury may be drawn off through the steel cock, D, and let in from a storage reservoir, G, at the top, by way of the tube, C, and a second steel cock, E. Small changes in the height of the mercury column such as were necessary in the final adjustment for reading may be effected by means of the powerful screw, S, working upon a thin sheet-steel plate which forms the bottom of the reservoir.

The shorter tube is 80^{cm} long up to the metallic point where the adjustment to constant volume is made, for in order to avoid pressures much too great for the strength of the bulb at high temperatures, the pressure at 0° must be chosen small.

The adjustment to constant volume was made in the older instrument at the end of the platinum capillary which constituted the connection between the manometer and the bulb, and which was melted directly into the top of the shorter tube (corresponding to A). This arrangement, which we at first retained, left the "unheated space" unnecessarily large, which for our purpose was a decided disadvantage. The influence of this "unheated space" (the space between the surface of the mercury in the manometer and the bulb, filled with gas like the bulb but not heated with it) upon the resulting temperature increases much more rapidly than the temperature itself. We have consequently since then adopted the arrangement of Chappuis* and closed the short tube (A) by a carefully fitted metallic cap with polished under surface. This cap was fastened upon the tube with sealing wax and carried near the middle, where the capillary tube opened into the glass tube, a metallic point 0·4^{mm} long to which the mercury column is brought at each reading. In this way the space above the meniscus was reduced from 2^{ccm} to 0·4^{ccm} in a tube of 2^{cm} diameter. The metal point, intentionally rounded off in order to allow of more accurate setting, was made of nickel, as was also the entire cap, in order that it might not become amalgamated by contact with the mercury.

On the upper side this cap was hollow and was originally intended to contain mercury; at the last, however, we preferred to fit into the space a massive block of copper bored with a cylindrical hole to admit the bulb of a mercury thermometer. In this way the temperature of the space above the mercury column (A) is more accurately determined than if the thermometer were hung at the side.

We had, to be sure, in the old instrument a thermo-element within this space itself, the wires being passed in through the glass; the observations made with it also gave good results but the arrangement was inconvenient and awkward. At a distance of 161·61^{mm} below the nickel point, the tube contained a second point of colored glass projecting out from the wall of the tube itself, for purposes of volumetric measurement. The volume included between the points was 50·723^{ccm}.

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*Chappuis, Trav. et Mém. du Bureau internat, vi, 28, 1888.

The longer tube (B) was 2^{m} long and its inside diameter 12^{mm}. Its upper end is connected by means of a ground glass joint and a metallic return tube with a wash bottle containing phosphoric pentoxide, thereby assuring dry air above the mercury column.

To change the gas in the bulb a water aspirator could be attached to the wash bottle to secure the diminished pressure necessary for drawing the mercury from the shorter tube (A) when the pressure in the bulb was low. When the mercury is thus drawn below the three-way cock, J, this may be turned and connection made through a second similar cock, K, either with the mercury pump or the gasometer and drying tubes. All connections were made with glass or sealing wax and tested from time to time to see that they were and remained absolutely air-tight. Rubber connections were conscientiously avoided.

The temperature of the mercury in the manometer was determined by the thermometer fitted into the cap above described and three other similar ones, whose bulbs dipped into short tubes containing mercury placed directly beside the long manometer tube at proper intervals and giving the temperature at the corresponding height in the long tube with sufficient accuracy.

The oven being always in a separate room, the changes of temperature about the manometer were very small and the time between observations necessary for regulating the oven temperature to the required degree of constancy, always sufficient to enable the thermometers to indicate any small changes which may have existed.

When mercury was let into the apparatus from the reservoir (G) at the top, more or less air bubbles always came with it, which collected in the main reservoir (R), having no means of escape. To avoid this in the new instrument, a short tube, D, with a glass cock, F, was introduced into R at its highest point, while the manometer tubes extended much deeper, thereby allowing the air to be drawn off at any time without endangering the gas in the bulb—a matter of the highest importance.

The manometer scale was ruled in millimeters for a length of 1·87^{m}, and carried upon a slider the knife-edge and a micrometer screw and vernier reading intervals of 0·02^{mm} directly. The largest scale error amounted to 0 04^{mm}.

The platinum capillary tube serving to connect the bulb with the manometer was soldered at one end into the metallic cap before mentioned and at the other attached to the stem of the bulb with sealing wax, this arrangement proving quite as trustworthy and convenient as a soldered joint. The sealing wax could be kept cool with water if necessary. The length of the capillary tube was much reduced in the new instrument (from $1{\cdot}37^{\mathrm{m}}$ to $0{\cdot}85^{\mathrm{m}}$), an improvement rendered possible by the electrical oven, which could of course be much better protected from radiation than a gas heater. Under the new arrangement a glass partition was amply sufficient to separate oven and manometer, a service for which before a brick wall had been deemed necessary. That the gas pressure in bulb and manometer may come quickly to a condition of equilibrium, the capillary tube should not be chosen less than two-thirds of a millimeter in diameter.

This flexible capillary also enabled us to move the thermometer bulb about at will for determining ice and boiling points after each heating; we found it, however, better to move it as little as possible, and in our later experiments the oven was mounted upon a framework provided with wheels and moving upon a track which enabled it to be pushed aside when the bulb was taken out, and ice and boiling point observations to be made at the same point by appropriately constructed apparatus. By this arrangement the amount of bending of the capillary required was very small.

Ice and boiling point observations were made after each heating during these experiments, not so much for their value as constants of the instrument and for the temperature determination as to determine any change which the measuring gas might have undergone at the higher temperatures.

The temperature as observed with the air thermometer was calculated according to the following formula:

$$H_0\left(1+\frac{v_{\prime}}{V_0}\cdot\frac{1}{1+at_{\prime}}\right)=\frac{H}{1+at}\left(1+3\beta t+\frac{v_{\prime}}{V_0}\cdot\frac{1+at}{1+at_{\prime}'}\right)$$

where

H_0 = Pressure at 0°.
H = " " t°.
V_0 = Volume of bulb at 0°.
$v_{\prime}$ = " " "unheated space" at the temperature of the room. (Changes in volume $v_{\prime}$ due to temperature neglected.)
$t_{\prime}$ and $t_{\prime}'$ = temperatures of "unheated space" with bulb in ice and at temperature t.
a = coefficient of expansion (technically *pressure coefficient* or *coefficient of expansion at constant volume*) of the gas between 0° and 100° (determined after each heating).
3β = cubical coefficient of expansion of the bulb.

The left side of the equation is a constant quantity for each filling if the zero point remains constant.

For the various bulbs used the values of V_0 and $v_{,}$ are quite different; the value in each case is therefore especially stated, and the percentage of effect which the "unheated space" has on the resulting *t*.

2. *Electrical Measurement.*

The measurement of the electromotive force of the thermo-elements was made by the "compensation" method. Cadmium cells served as standards of potential-difference.

The cold junctions of the thermo-elements were contained in glass tubes surrounded by melting ice.

A Siemens and Halske voltmeter was of great service in the regulation of the temperature of the oven.

3. *Experiments with glass bulb.*

A bulb of Jena glass No. 59^{III} was used for the measurements between 200° and 500°. The gas was hydrogen, chosen chiefly in order to see whether this gas, whose expansion is made the basis of modern thermometry, can be advantageously used in practice above 200°.

In these lower temperatures the thermo-elements do not form a good basis of comparison for the air thermometer; it is, however, perfectly possible to detect any change which the gas may have undergone during the heating through changes in the ice point or coefficient of expansion.

Dimensions of Bulb.—The glass bulb had the form of a cylinder with rounded ends, 16^{cm} long and $3{\cdot}5^{\text{mm}}$ outside diameter. The stem was $40{\cdot}0^{\text{cm}}$ long, $0{\cdot}75^{\text{mm}}$ in inside diameter, and bent to a right angle nearly in the middle.

The volume as measured at the beginning was $166{\cdot}53^{\text{ccm}}$, and at the end $166{\cdot}43^{\text{ccm}}$, the determination being made by filling with distilled water and weighing. The bulb had already been seasoned by repeated heatings to 500° before the first determination was made.

Unheated Space.—The temperature of the stem, as well as of the platinum manometer capillary, was determined by mercury thermometers placed at intervals close by and from whose readings an integral temperature of the unheated space, in this case amounting to $2{\cdot}701^{\text{ccm}}$, was obtained. This value is the result of a volumetric determination made at the beginning of the experiments. A determination by weighing with water at the close gave $2{\cdot}668^{\text{ccm}}$.

Heating arrangements.—For all the observations with the glass bulb a nitre bath was used, heated by Bunsen burners. The bath was contained in a cast iron kettle 34^{cm} high and 18^{cm} in diameter, provided with a cover through which the thermometer bulb and the porcelain tubes containing the thermo-element were passed, the whole being protected from radiation by a thick outer cylinder of fire-clay. The bath was stirred continually by a turbine wheel driven from outside. Inasmuch as the bath when cold solidified, the kettle was first heated to 250° empty and the previously melted nitre poured in through a funnel. At the close of the day's measurements the nitre was drawn off while still hot with a siphon.

Hydrogen.—The hydrogen used was generated electrolytically from dilute sulphuric acid, and before being admitted into the bulb was passed through two wash bottles containing alkaline solution of pyrogallic acid to remove traces of oxygen present, and drying tubes containing calcium chloride and phosphoric pentoxide. Failure to take this precaution always resulted in a fall of the ice point after heating, amounting to from 3 to 5^{mm} mercury pressure. This difference diminished with subsequent heatings (the heatings were each about five hours long), as may be seen in the following instance:

	Gas pressure at 0·0°.
Bulb freshly filled	$567{\cdot}80^{mm}$ Hg.
After 1st heating (to 510°)	564·63 "
" 2d " " 530	564·15 "
" 3d " " 500	563·61 "
" 4th " " 540	562·83 "
" 5th " " 540	562·56 "

The phenomenon is to be attributed to a gradual combining of the hydrogen with the oxygen present and occurs even when the temperature is not carried above 400°. Before the final filling the bulb was always evacuated at a temperature of 500° and allowed to stand for several hours, being "rinsed" from time to time with dry hydrogen. The generating apparatus and connections were perfectly air-tight and remained so throughout.

Expansion of Bulb.—For the glass bulb 3β is assumed equal to 0·000018,* a value determined for the temperature range 0°–100°. The "unheated space" affects the result (t) 2·6 per cent at 200° and 4·1 per cent at 500°.

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*Thiesen, Scheel and Sell, Wissensch. Abhandl. d. Phys.-Tech. Reichsanstalt, ii, 129, 1895.

TABLE I.

Bulb (No. 1).—Jena glass No. 59^{III}. Gas—Hydrogen.

$V_0=166{\cdot}38^{ccm}$. $v_{,}=2{\cdot}70_1$. $3\beta=0{\cdot}000018$.

After filling.	H_0	a	t	e_1	Obs.-Calcul.
1st day	597·17	0·003657			
2d "	597·18	0·003658			
4th "			397·1°	3072	—0·3°
			393·1	3043	—1·2
			444·2	3485	—0·2
			518·4	4230	—0·8
5th "	597·17	0·003661			
6th "			342·4	2573	—0·7
			396·1	3073	—1·4
			458·1	3647	—0·5
			458·1	3656	—1·2
			487·3	3930	—0·8
7th "	597·19	0·003661			
Bulb freshly filled.					
1st day	638·87	0·003656			
2d "			309·3	2275	—0·7
			365·8	2787	—0·8
			406·8	3156	+0·8
			406·3	3158	—0·3
			462·1	3691	—1·0
			510·0	4147	—0·6
3d "	638·86	0·003656			
6th "			332·0	2470	+0·3
			371·9	2835	+0·1
			407·2	3163	0·0
			452·2	3586	+0·1
			502·5	4071	+0·3
7th "	638·72	0·003656			
8th "			311·4	2286	+0·2
			350·6	2640	+0·1
			405·5	3145	+0·3
			460·2	3653	+1·0
9th "	638·72	0·003655			
10th "			251·4	1763	+0·1
			250·7	1757	+0·1
			302·4	2201	+0·7
			413·8	3219	+0·7
			465·5	3708	+0·6
			510·7	4144	+0·4
11th "	638·67	0·003654			
15th "			234·8	1624	0·0
			254·2	1783	+0·6
			275·5	1967	+0·5
			551·3	4546	—0·2
			529·4	4322	+0·7
			514·7	4181	+0·5
16th "	638·26	0·003656			

Table I gives the results obtained from two separate hydrogen fillings between 200° and 500°. It contains the ice point (H_0), coefficient of expansion of the gas between 0° and 100° (a), the temperature as observed with the gas thermometer and calculated according to above formula (t), with the corresponding E. M. F. of the thermo-element T_1 in microvolts (e_1).

For this element a curve has been drawn based upon the mean of all the observations made with it between 200° and 1150°. Its form is given by the following table.

TABLE II.

Thermo-element T_1.

	Microvolts.		Microvolts.
200°	1334	700°	6044
250	1752	750	6566
300	2186	800	7096
350	2635	850	7634
400	3096	900	8180
450	3566	950	8734
500	4044	1000	9296
550	4531	1050	9863
600	5027	1100	10434
650	5531	1150	11009

The last column of Table I ("Obs.-Calcul.") contains the difference between any particular observed temperature and the corresponding point of this curve in degrees. The mean value of this error for this set of observations amounts to ±0·64° and is to be charged rather to the thermo-element than to the gas thermometer.

The differences between the separate values of the zero point (H_0) and of the coefficient of expansion (a) are not greater with the first filling than the maximum error of observation, which in reading barometer and manometer might in unfavorable cases combine to amount to $0{\cdot}05^{mm}$. The ice point in the second series of observations showed a tendency to fall, the amount of which, if we may except the last heating when the temperature was forced up to 550°, was $0{\cdot}14^{mm}$ (maximum).

4. *Experiments with porcelain bulbs glazed inside and out.*

Bulbs.—Temperatures above 500° were next measured with a bulb of this type. These bulbs, in a form adapted for this purpose, cannot, on account of the fine capillary tube, be glazed by simply dipping a finished bulb in the glazing solution and burning. Deville and Troost succeeded in glazing their bulbs on the inside, only by preparing bulb and capillary in separate pieces and melting them together in the oxy-hydrogen flame.

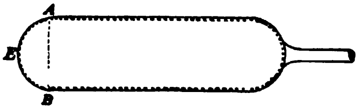
Inasmuch as the bulbs prepared in this way are often not air-tight, we have preferred to take the completely moulded though not burned bulb lacking only the end piece E (fig. 2), cover the inside with glazing solution, set the similarly smeared end piece on and burn the whole at once.

This gives of course on the inside an unglazed ridge some 2^{mm} wide and the same high where the cap is set on, but this has given no trouble.

To obtain a perfectly glazed outside surface (very essential) the bulbs must be hung up for burning by the stem, free from contact with each other or surrounding bodies. If it is desirable that the stem be curved for dipping in a bath, the finished stem may readily be bent in the oxy-hydrogen flame according to requirements.

The bulbs used by us were made in the "Königliche Porcellan-Manufactur" Berlin and have the form given in fig. 2.

2



The length was about 12^{cm}, diameter $3·7^{cm}$, thickness of the walls 2^{mm} and the volume approximately $100^{cu\ cm}$.

The length of the capillary stem was regulated according to our necessities, the original length being 60^{cm} and the diameter inside $0·85^{mm}$. At the open end, it was bored out to a diameter of 2^{mm} to admit the end of the platinum capillary leading to the manometer; the joint was then made air-tight with sealing wax.

As coefficient of expansion the value obtained by Holborn and Wien for Berlin porcelain is adopted.

The "unheated space" with bulb No. II, mounted as here described, was $2·837^{ccm}$. Effect on resulting t at 500°, 7·5 per cent; at 900°, 11·3 per cent.

Nitre Bath.—For a while the heating arrangements were retained as before, but above 500° the nitre bath decomposed more rapidly, in consequence of which it became strongly alkaline and its melting point sank; the outside glazing of the bulb was also considerably affected but remained air-tight throughout the observations.

The highest temperature attainable under these conditions is about 750°, but the mechanical arrangement for stirring could not be used above 600°. With an especially powerful heater and a smaller bath an attempt was made to carry observations still higher, but at about 810° a violent decomposition set in and in a few moments the entire bath had boiled away.

Hydrogen in porcelain bulbs.—At first one of these bulbs (No. II) was used filled with hydrogen, as in the case of the glass bulb; here, however, the bulb was evacuated at 700° instead of 500°, then rinsed as before with the dry gas. Table III contains two sets of results obtained under these conditions.

TABLE III.*

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Hydrogen.

$V_0=101\cdot13_6^{\text{ccm}}$. $v_{,}=2\cdot83_7^{\text{ccm}}$. $3\beta=0\cdot0000132$.

After heating.	H_0	a	t	e_1	Obs.-Calcul.
1st day	529·02				
1st " (2)	529·03				
2d "			309·3°	*2258*	*+1·2°*
			410·1	*3179*	*+1·2*
			527·6	*4303*	*+0·8*
			611·4	*5119*	*+2·4*
4th "	527·56				
4th "	527·58	0·003669			
5th "			407·9	*3158*	*+1·3*
			521·9	*4234*	*+2·6*
			601·8	*5015*	*+3·0*
			708·6	*6100*	*+3·2*
6th "	525·36	0·003672			
7th "			499·1	*4018*	*+1·8*
			609·6	*5093*	*+3·0*
			653·3	*5527*	*+3·7*
			729·3	*6310*	*+3·7*
8th "	522·48	0·003678			
Bulb freshly filled.					
1st day	532·03	0·003665			
3d "			536·6	*4393*	*+0·7*
			613·6	*5142*	*+2·2*
			677·6	*5777*	*+3·5*
			725·2	*6269*	*+3·6*
4th "	529·37	0·003675			

After each heating a considerable fall in the ice point (H_0) is noticeable and an increase in the coefficient of expansion of the gas. This seems to point to a chemical action at the higher temperatures between the hydrogen and the walls of the bulb and the generation of water vapor.

Nitrogen.—For the reason named, the use of hydrogen at high temperatures was abandoned and nitrogen substituted. This was obtained from atmospheric air by passing it through from four to six wash bottles filled with an alkaline solution of pyrogallic acid, thence after continuing on through the usual drying tubes it was used as before, first for rinsing at 700° and then for the definite filling. Especial precautions were here taken to free the bulb from hydrogen, the evacuated bulb standing the entire day at 700°, the pump being operated at intervals. The drying tubes were also evacuated before the nitrogen was admitted. Table IV gives the values obtained with the same bulb (No. II) and nitrogen, the heating being done as before in the nitre bath.

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* Values of *e* printed in italics were not used in the determination of Tables II and X.

TABLE IV.

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$V_0=101·13_6^{ccm}$. $v_{,}=2·83_7$. $3\beta=0·0000132$.

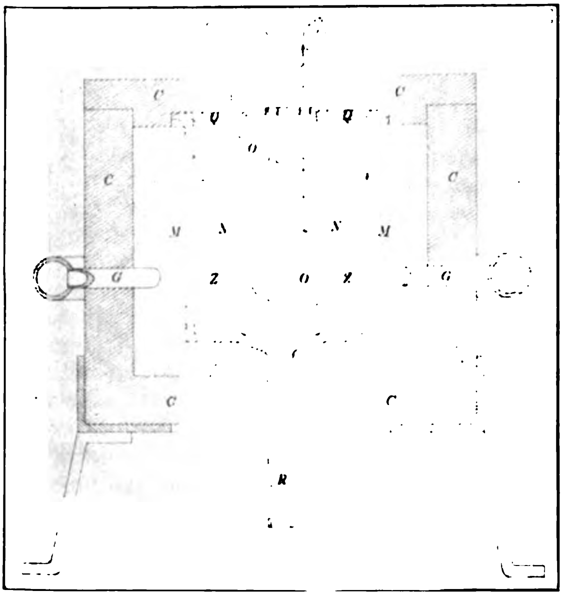
After filling.	H_0	a	t	e_1	Obs.-Calcul.
1st “	506·32	0·003677			
2d “			520·8°	*4249*	*−0·4°*
			606·3	*5092*	*−0·2*
			680·8	*5844*	*+0·2*
3d “	507·92	0·003681			
4th “			490·0	*3942*	*+0·6*
			573·7	*4760*	*+0.5*
			702·8	*6050*	*+2·2*
			706·9	*6088*	*+2·7*
6th “	508·54	0·003681			
Bulb freshly filled.					
1st day	432·87	0·003675			
3d “			280·4	2012	+0·3
			313·4	2301	+0·5
			512·3	4157	+0·6
4th “	432·62	0.003676			
6th “			506·0	4100	+0·2
			605·2	5087	−0·8
			633·8	5369	−0·2
7th “	432·41	0·003680			
8th “			612·2	5165	−1·6
			649·5	5537	−1·1
			690·9	5949	−0·1
			698·1	6015	+0·9
9th “	432·86	0·003680			
9th “			195·1	1295	−0·1
11th “			219·1	1488	+0·5
11th “			676·4	5789	+1·1
			673·9	5756	+1·8
14th “	433·09	0·003680			
15th “			576·7	4786	+0·9
			731·9	6366	+1·0
			735·1	6390	+1·9
16th “	433·61	0·003684			
Bulb freshly filled.					
1st day	417·29	0·003671			
2d “			813·1	7221	+1·4
			816·1	7253	+1·5

The first filling, in spite of the care exercised, still shows signs of the presence of hydrogen, afterward the changes in ice point and expansion coefficient become noticeably smaller, though the latter persists in a tendency to increase throughout.

The mean difference between the observed temperatures and those obtained from the curve (Table II) is ± 1·06°.

Zinc bath.—In order to continue these observations to a higher temperature an apparatus for boiling zinc was provided. The boiling kettle proper consisted of two concentric wrought iron cylinders, M and N (fig. 3), welded to a common bottom.

3



The ring-shaped space, Z, was filled with zinc while the inner cylinder, N, contained the bulb of the gas thermometer and the thermo-element, the latter protected as before by a porcelain tube. The whole was closed by a carefully fitted iron cover protected as much as possible by asbestos and fire-clay against loss of heat by conduction, and surrounded by a jacket of fire-clay pierced by a tube at the bottom where the zinc vapor passed off and the six blowpipes furnishing the heat. The latter were arranged in a spiral and directed tangentially against the zinc kettle.

It was unfortunately not possible to place the thermometer bulb and thermo-element directly in the zinc vapor on account of the difficulty in packing them so as to prevent the vapor from escaping, consequently they were enclosed in a sheet iron cylinder made fast to the cover of the kettle. Around the outside of this cylinder the vapor circulated freely and took fire on coming in contact with the air at the end of the tube R.

Table V contains the results of two trials with bulb No. II in this kettle.

Table V.

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$V_0=101{\cdot}13_6^{\mathrm{ccm}}$. $v_{,}=2{\cdot}83_7$. $3\beta=0{\cdot}0000132$.

After filling.	H_0	a	t	e_1	Obs.-Calcul.
1st day	415·40	0·003669			
3d "			Heated to 700°.		
4th "	415·80				
4th "			804·2°	7219	−7·4°
			906 0	8293	−4·2
			920·3	8415	−1·0
			933·7	8564	−1·0
5th "	417·05	0·003669			
7th "			909·4	8304	−1·8
			914·8	8351	−0·7
			915·4	8354	−0·4
			916·6	8367	−0·3
			917·5	8373	0·0
			918·3	8382	0·0
			918·9	8387	+0·1
			919·4	8392	+0·2
			920·0	8393	+0·7
			920·4	8398	+0·7
8th "	417·29	0·003671			

An agreement between observed and calculated values, as will be readily seen from the table, is only to be obtained near the boiling point of the zinc, or after the generation of the vapor has begun to take place freely. The high temperature 933·7° on the first day was obtained by overheating the apparatus after the zinc was for the most part evaporated.

Electric Oven.—The second bulb of this sort (No. III) was heated electrically.

The coil (see fig. 1) consisted of bare nickel wire 2^{mm} in diameter wound upon a porcelain or fire-clay tube lying horizontally. The diameter of the tube was $4{\cdot}8^{\mathrm{cm}}$ (inside), the length 35^{cm} and the thickness $0{\cdot}3^{\mathrm{cm}}$ to $0{\cdot}5^{\mathrm{cm}}$. The spaces between the separate turns of wire (of approximately the same width as the wire itself) were filled with clay which baked firmly to the tube, to prevent the wire from slipping and short circuiting when hot. In order to reduce the loss of heat into the room to a minimum, the coil was first surrounded with one, later with two concentric tubes of clay, separated from each other as well as from the coil by a thin air jacket (1^{cm}). These spaces were closed at the ends and the tubes held in place by a tight packing of asbestos. Each tube was provided at the ends with a clay cover* fitting tightly, and between the covers was also left an air space of about a centimeter. Openings were filed in the covers to admit the stem of the thermometer bulb and the insulating tubes carrying the thermo-elements. This oven, while maintaining a temperature of 1000°, consumed about 1400 watts.

The thermometer bulb lay symmetrically in the oven tube resting upon three very small pieces of fire-clay, especial care being taken that it nowhere touched the oven. For each set of measurements two or three thermo-elements were used, stretched through the oven from end to end so that the junction could be brought to any point along the bulb whose temperature was required. The fall of temperature along the bulb amounted to not more than 6°, in the mean perhaps to half that. The results obtained from the several elements were all referred to the element T_{II}, a careful comparison with T_I over the entire range of temperature having been made previously; the mean of these is the value given in the table. Inasmuch as this mean gave an excellent agreement with the gas thermometer in two so different sets of conditions (nitre bath and electric oven), and the temperature conditions within the oven can only improve as the temperature rises (compare § 6), no more accurate determination of the error due to variations of temperature along the bulb was made.

Table VI contains two sets of results obtained in this oven. In one respect the above described arrangement made a distinct gain over the previous one; with the bath the bulb had to be provided with a long bent stem for dipping into the kettle without unduly heating the sealed joint where the manometer capillary was attached; here a short straight one sufficed. The "unheated space" was thus materially diminished, and the error from this cause also. The effect of the unheated space upon t was here 9·7 per cent at 800° and 12·3 per cent at 1100°.

The temperature was not often carried over 1100°, only once a temperature of 1161·5° was reached, but directly following a large error in the ice point ($1{\cdot}30^{mm}$) was recorded, which shows 1100° to be about the limit of the practical application of these bulbs. To be sure, differences in the zero point appear below this temperature; these in the calculation are distributed among the observations of a particular series according to the *time.*

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* These clay covers (made by Haldenwanger, Charlottenburg), though perfectly able to withstand the high temperatures, were and remained of almost the consistency of chalk and could be filed or sawed at will.

TABLE VI.

Bulb (No. III).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$V_0=106{\cdot}01_6^{ccm}$. $v_,=2{\cdot}80_7^{ccm}$. $3\beta=0{\cdot}0000132$.

After filling.	H_0	a	t	e_1	Obs.-Calcul.
1st day	419·23	0·003672			
2d "			Heated to 1000°		
4th "	419·91	0·003669			
6th "			775·7°	6866	−2·7°
			826·0	7412	−3·4
			885·1	8034	−1·6
			932·1	8545	−0·9
			932·6	8553	−1·1
			934·5	8575	−1·2
			982·2	9128	−2·3
			984·6	9141	−1·7
			1058·8	9996	−2·9
			1058·3	9990	−2·8
			990·6	9203	−1·1
			897·3	8167	−1·5
			804·4	7162	−1·8
			700·6	6075	−2·4
7th day	421·12	0·003672			
9th "			Heated to 1050°		
11th "	421·61	0·003675			
13th "			783·1	6928	−1·1
			864·1	7797	−0·9
			924·5	8461	−0·9
			975·6	9044	−2·1
			1044·6	9824	−2·0
			1013·0	9462	−1·7
			1015·9	9496	−1·8
			945·0	8689	−1·0
			899·3	8184	−1·1
			833·0	7462	−1·1
14th "	422·33	0·003671			
16th "			820·2	7318	−0·5
			916·8	8352	+1·2
			1002·4	9323	0·0
			1097·9	10404	+0·5
			1127·8	10708	+0·5
			1061·8	9987	+0·9
			934·9	8559	+0·6
			861·5	7760	−0·1
18th "	422·89	0·003672			

Bulb freshly filled.	H_0	a	t	e_1	Obs.-Calcul.
1st day	412·66	0·003673			
2d “			803·2	7123	+0·7
			891·8	8094	−0·3
			1003·9	9311	+2·6
			1099·6	10400	+2·6
			1161·5	11128	+1·2
			1113·6	10574	+1·4
			1029·5	9616	+1·2
3d “	413·96	0·003671			
4th “			793·8	7043	−1·2
			901·6	8200	−0·2
			999·1	9292	−0·5
			1107·4	10517	+0·2
			1049·2	9844	+0·9
			938·1	8591	+1·0
			847·8	7610	0·0
5th “	413·99	0·003675$_5$			
6th “	413·90	0·003674			
8th “	413·97				

In order to be sure that the apparatus had remained air-tight, at the close of the observations several ice points were taken on different days. These agree within the limits of the error of observation. The mean difference between observed and calculated values of $t = \pm 1{\cdot}52°$.

5. *Experiments with bulbs glazed outside only.*

The experiments with bulbs left unglazed on the inside did not differ materially from the preceding. The heating was all done in the electric oven. The old manometer was still used for the pressure measurements, but the unheated space was still further diminished by the use of a metallic cap for closing the short tube of the manometer at the top so that the correction at 500° amounted to only 4·7 per cent, at 1000° to 7·2 per cent, and at 1100° to 7·8 per cent of t.

The gas pressure was chosen considerably smaller than before, because the bulbs were to be heated above the melting point of the glazing; it was therefore necessary that the maximum pressure reached should not exceed the atmospheric pressure. The melted glazing, being thus continually pressed *into* the pores of the porcelain, held tight. Only a slight excess of pressure inside at this temperature suffices for the gas to filter through and escape.

Considerable difficulties were here experienced from the sticking of the melted glazing to the oven wall if the slightest contact occurred, in which case it was almost impossible to remove the bulb after cooling without cracking the glaze. It would then be no longer air-tight, nor in fact of any further use for our purposes. In this way all the bulbs used were in a short time ruined.

TABLE VII.

Bulbs (Nos. IV and V).—Berlin porcelain glazed outside only. Gas—Nitrogen.

Bulb No. IV, $V_0 = 103{\cdot}47_8$ ccm. $v_\prime = 1{\cdot}77_0$ ccm. $3\beta = 0{\cdot}0000132$.
" V, $V_0 = 100{\cdot}21_0$ ccm. $v_\prime = 1{\cdot}66_4$ ccm. " "

After filling.	H_0	a	t	e_1	Obs.-Calcul.
		Bulb No. IV.			
1st day	171·02	0·003669			
4th "			545·0°	4480	0·0°
			641·5	5466	−2·1
			742·2	6505	−2·0
			843·9	7572	−0·4
			930·6	8523	−0·4
			1014·0	9485	−2·7
5th "	173·30	0·003663			
6th "			584·0	4886	−2·0
			693·8	5999	−1·8
			800·9	7126	−1·9
			896·3	8170	−2·8
			1010·2	9457	−4·0
7th "	173·26	0·003666			
		Bulb No. V.			
1st "	122·09	0·003667			
2d "			898·3	8145	+1·5
			906·3	8260	−1·0
			901·0	8238	−4·3
			Cont. to 1200°.		
3d "	125·01	0·003669			
4th "			948·8	8789	−6·1
			956·9	8884	−6·5
			957·4	8883	−5·9
			1069·7	10097	−0·8
			1080·9	10222	−0·6
			1077·1	10170	+0·2
			1080·2	10203	+0·4
			1149·0	10958	+3·4
			1150·4	10965	+4·2
			1149·2	10943	+4·9
			1157·2	11024	+5·9
			1036·3	9649	+5·2
			1029·2	9575	+4·6
5th "	126·21	0·003675			
6th "			900 8	8266	−7·0
			921·9	8505	−7·5
			987·1	9211	−5·4
			Cont. to 1225°.		
			997·0	9228	+3·0
			989·4	9160	+1·4

After filling.	H_0	a	t	e_1	Obs.–Calcul.
8th day	126·66	0·003678			
9th "			918·3	8435	—4·8
			923·9	8502	—5·3
			943·6	8704	—3·7
			1113·6	10630	– 3·5
			1117·5	10664	– 2·5
			Cont. to 1215°.		
			1066·4	10008	+ 3·7
			1066·8	10018	+ 3·2
			940·9	8622	+ 1·0
10th "	127·10	$0{\cdot}003679_5$			
Bulb freshly filled.					
3d day	148·81				
5th "	148·85	0·003667			
8th "	148·88	0·003668			

In Table VII are given the results obtained with two of these bulbs. One (numbered IV in the table) served for measurements up to 1000° and was intended to furnish a control upon the results obtained previously from bulbs glazed on both sides.

The values given by the gas thermometer with this bulb are all too small when compared with the element T_1. It is nevertheless a matter of doubt whether this difference arises entirely from the nature of the bulb; it may be partly due to the change in the volume of the unheated space.

In regard to the changes in the zero point here noticed, it should be borne in mind that as the quantity of gas is here smaller, a small increase would produce a comparatively greater effect upon the pressure at 0°.

The other unglazed bulb (numbered V) was several times heated above 1200° and observed by rising as well as by falling temperature, as a result of which the differences between the values obtained and the normal curve are found to change sign during the heating, in fact to form a loop about the curve. The cause of this phenomenon we were not able to discover, for it was not possible, on account of the thin wall of the bulb, to heat it above 800° under vacuum, and further experiments with thick-walled bulbs could not conveniently be undertaken at that time.

A series of observations of the ice point and expansion coefficient was here also undertaken with a fresh gas filling at the close of Table VII, to see that the connections had remained tight.

In regard to the cause of the more or less systematic ice point variations throughout the observations, it is emphatically our opinion that it lies in the porcelain wall itself. The variations are always greatest after the first heating, so that quite probably a chemical action or a setting free of absorbed gas is responsible for it. If porcelain at high temperatures were porous the change with each further heating should be as great as with the first. A change in the volume of the bulb cannot explain the phenomenon, for bulb No. III was weighed after the observations and its volume determined. The result showed an *increase* in volume amounting to 0·003, a result which would have an opposite effect to that under consideration.

Concerning the experiments of Teudt* tending to show a dissociation of atmospheric nitrogen at temperatures below 500° in which connection he has quoted experiments of Holborn and Wien, it may be said that we used the elsewhere mentioned platinum bulb at first with atmospheric nitrogen at temperatures considerably above 500° and detected no change in the gas whatever. We hope also later to investigate the behavior of porcelain bulbs with chemically pure nitrogen as well.

6. *Experiments with the platin-iridium bulb.*

The Bulb.—The platin-iridium bulb used was similar in form to the glass bulb first described and was made by the firm of Heräus in Hanau. It contained as much iridium as could be alloyed with the platinum and allow of its being properly worked—about 20 per cent. The length was 17^{cm}, outside diameter 4^{cm} and the thickness of the wall $0·5^{mm}$. It was made from three pieces of sheet metal, the main cylinder and two rounded end pieces, welded together and giving of course a seam around each end and down the middle. These seams were afterward protected by a thick layer of platinum, melted and dropped on to the hot bulb—it then proved and has since remained perfectly tight. The stem where it was welded on to the bulb (welding seam also strengthened with platinum) was also made of the 20 per cent alloy for a distance of some 10^{cm} out from the bulb, where it was reduced to 5 per cent for the remaining 20^{cm} of its length. The 5 per cent alloy is much less brittle and, therefore, more convenient to handle. In outside diameter the stem was 2^{mm} and inside $0·75^{mm}$. It was connected with the capillary tube leading to the manometer by means of a short overlapping glass tube sealed at both ends with sealing wax. It was possible by carefully heating to draw the sealing wax in between glass and platinum until the entire space around the ends of the two capillaries was filled, thereby adding as little as possible to the volume of the "unheated space."

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* Teudt, Zeitschr. f. physikal. Chem., xxvi, 143, 1898.

The volume of the bulb at 0° was 208·222^{ccm} and the weight 308 grams. The final determination of the volume was made after the bulb had been several times heated to the highest temperature observed. The volume was chosen larger than in the case of the porcelain bulbs previously used in order to still further diminish the effect of the unheated space. *The required correction here was thus only 1·1 per cent of t at 500° and 1·9 per cent at 1100°.*

Before being attached to the thermometer the bulb was boiled for several days in concentrated nitric acid. When heated to 1100° or 1200° the outside surface turned black, a phenomenon probably to be attributed to the oxidation of the iridium. Afterward, when the temperature was carried up to 1300° the bright metallic color returned—indicating a reduction of the iridium oxide.

Gas filling.—Before filling the bulb with gas it was exhausted with the mercury pump and in this condition heated, at first to 850°, *afterward to 1300°*, the pump being operated from time to time throughout and a sharp vacuum maintained even at the latter temperature.

For the purpose of having an elementary gas for the final measurements, nitrogen was generated from ammonium nitrite and passed through four wash bottles containing the usual pyrogallic acid solution, then through drying tubes and into the hot bulb, which was then allowed to cool. When it had cooled down to the temperature of the room a further small quantity of gas was added or taken away until the pressure desired for the observations was obtained. This pressure was always so chosen that at the highest temperature to be measured, the maximum pressure exerted upon the walls of the bulb would not be above one atmosphere.

Electric Oven.—The oven was similar to that used in heating the porcelain bulbs; unfortunately, however, the tubes at our disposal upon which the coils could be wound were a few millimeters smaller than might have been desired, thereby giving rise to two sorts of difficulties. First, the irregularities of temperature within the oven made themselves strongly felt on the bulb of the thermometer, and secondly, inasmuch as the space between bulb and oven wall was very narrow the wires of the thermo-elements were with difficulty prevented from short circuiting through the metallic wall of the bulb. Their insulation was accomplished in these experiments by very thin porcelain tubes slipped on to the elements wherever such a contact was possible. At temperatures of 1000° and above, however, where the porcelain begins to act sensibly as a conductor, a leakage began to be noticeable from the oven coil into the elements through the tube carrying the coil, the three bits of fire clay which served to hold the bulb in place in the oven, and the metallic bulb itself. The error due to this leakage within the range of temperature observed (to 1150°) was readily eliminated by reversing the current in the oven.*

For temperatures above this point a larger oven is being prepared. The oven as used up to the present is shown in cross section in fig. 1.

Temperature variations along the bulb.—The difficulty caused by the variations of temperature within the oven we succeeded in overcoming for the most part by varying the winding of the coil somewhat.

Instead of a uniform space between the separate turns of wire approximately equal to the diameter of the wire (2^{mm}) as we had previously used it, it was only so wound at the ends, the turns in the middle for some 10^{cm} being twice as far apart (4^{mm}) and coming gradually closer together toward the ends, i. e. roughly, a logarithmically wound coil.

Before the oven thus equipped was used for thermometric measurements the differences of temperature at various points within were determined as follows: Two thermo-elements were melted together at their junctions and drawn from point to point through the empty tube at various temperatures. Especially thin elements were chosen for this purpose, $0{\cdot}25^{mm}$ diameter instead of the usual $0{\cdot}6^{mm}$, in order to reduce the heat conducted away from the junction by the wires themselves to a minimum.

Table VIII contains the results of this trial for the old and the new oven coils, the dimensions of the tube being approximately the same for both. In the first case (uniform winding) the conditions improve with the higher temperatures, which seems to indicate that the tendency to a condition of equilibrium through radiation is stronger than the loss at the ends from conductivity. The presence of the platin-iridium bulb in the tube diminishes the irregularities some 3° at the lower temperatures, at 1000° scarcely any. The placing of fire-clay partitions in the tube close to the ends of the bulb also influences the results between 500° and 900°; between these limits the temperature as measured by the gas thermometer is raised some 3·5° without changing the temperature relation between the middle and end of the bulb; that is, the partitions affect only the radiation from the end surfaces.

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* A simple reversal of the current is insufficient for correcting a large error from this cause, as the resistance of porcelain increases with the time of passage of the current, and one must, therefore, wait until the resistance is approximately constant. In the observations here presented the reversal of the current influenced the thermo-elements about 0·5° at 1000° and 1·5° at 1100°, and some five minutes were required to produce constant conditions.

TABLE VIII.

Variations of temperature within electric oven.

Distance of thermo-electric junction from middle-point of oven.	Fall in temperature as compared with center of oven.						
	Coil wound uniformly.			Coil wound logarithmically.			
	At 640°	At 840°	At 1040°	At 620°	At 820°	At 1010°	At 1150°
4·0cm to the right	− 3·4°	− 3·4°	−2·7°	+1·3°	+0·6°	−0·3°	−0·7°
7·5 " "	−14·7	−11·7	−8·7	+3·5	+2·1	−0·3	−1·8
4·0 " left	− 3·2	− 2·7	−1·9	+1·8	+1·2	+1·4	+2·0
7·5 " "	−14·4	−11·1	−9·9	+1·9	+1·8	+2·7	+1·7
10·0 " "				+0·1	+0·7	+2·4	+0·8

Table IX contains the results obtained with the platin-iridium bulb in the new form of coil, excepting the first two sets, which were made with the uniform winding and partitions in the tube close to the end of the bulb. For these two cases an integral value of the distribution of temperature along the bulb as measured at the time has been added as a correction. We lay no especial stress upon the agreement of these values with the following ones and give the results only because they happen to have been made with the same gas filling. Observations during which the oven current was reversed are indicated in the table by an asterisk (*).

The values for the electromotive force e_2 refer to the element T_2, which throughout the observations lay at the middle point of the bulb. The results obtained with the logarithmically wound spiral contain no correction for variations in temperature along the bulb, although, as may be seen from Table VIII, the ends of the bulb for the lower temperatures are somewhat overheated. The values in the last column (Table IX) give the differences between the observed temperatures obtained from the gas thermometer and those taken from a mean curve drawn through the plotted readings of the thermo-element T_2. *The mean value of the error thus obtained amounts to ± 0·85.*

TABLE IX.

Bulb (No. VI).—Platinum with 20 per cent iridium. Gas—Nitrogen.

$V_0=208{\cdot}22_2$ ccm. $v_{,}=0{\cdot}87_0$. $3\beta=0{\cdot}000025$.

After filling.	H_0	a	t	e_2.	Obs.-Cal.
1st day	286·44	0·003662			
4th "			625·9°	*5399*	*0·0°*
			626·7	*5404*	+*0·3*
			710·3	*6272*	+*0·6*
			815·9	*7408*	+*0·8*
			908·4	*8439*	+*1·1*
			1003·5	*9530*	+*1·7*
			1121·6	*10910*	+*4·5*
			1128·3	*11000*	+*3·8*

After filling.	H_0	a	t	e_2.	Obs.-Cal.
5th day	286·35	0·003665			
8th "			705·3	*6252*	*—2·5*
			818·9	*7472*	*—2·0*
			915·7	*8565*	*—2·0*
			1015·6	*9710*	*—1·4*
			1130·0	*11074*	*—0·4*
10th "	286·39				
19th "	286·39	0·003662			
20th "			624·3	5389	—0·6
			809·4	7346	—0·1
			903·6	8387	+0·9
			1009·7	9614*	+0·8
			1107·2	10763*	+2·3
21st "	286·36				
22d "			511·1	4239	+1·1
			512·0	4255	+0·4
			550·6	4643	—0·4
			657·8	5743	—1·4
			702·0	6206	—1·5
			754·8	6765	—1·2
			856·2	7872	—0·8
			945·0	8882	—1·1
			996·6	9488*	—1·6
			1044·8	10036*	+0·2
			1047·2	10065*	+0·2
			1096·0	10645*	+0·8
24th "	286·30	0·003663			
24th "			540·4	4539	—0·1
			541·9	4556	—0·3
			614·3	5285	—0·4
			715·4	6332	—0·1
			811·6	7375	—0·5
			915·9	8541	—0·4
			1012·5	9653*	+0·3
			1100·0	10693*	+0·8
25th "	286·31				
25th† "			515·7	4291	+0·4
			615·1	5291	—0·2
			719·2	6371	0·0
			819·1	7452	0·0
			909·7	8449	+1·6
			1020·8	9748*	+0·5
			1127·5	11025*	+1·1
26th "	286·79	0·003662$_5$			
Bulb freshly filled.					
1st day	294·34	0·003666			
2d† "			528·3	4416	+0·2
			613·6	5277	—0·3
			1003·8	9547*	+0·6
4th "	294·33				

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† At the close of the observations the oven was maintained for a considerable time at 1300°.

Table X gives the values of the E. M. F. for the element T_2.

TABLE X.

Thermo-element T_2.

	Microvolts.		Microvolts.
500°	4141	850°	7794
550	4633	900	8356
600	5135	950	8927
650	5647	1000	9507
700	6169	1050	10101
750	6700	1100	10703
800	7242	1150	11315

Expansion coefficient of platin-iridium.—In regard to the calculation of the temperatures given by the gas thermometer with the platin-iridium bulb, attention should be called to the fact that the round number 0·000025 has been adopted as the coefficient of volume-expansion of platin-iridium (3β).

This corresponds for a 20 per cent alloy to the figures given by Benoît* for observations upon pure platinum, pure iridium, and a 10 per cent alloy for temperatures 0°–100°.

It is probable that this coefficient is higher at higher temperatures, but few trustworthy observations are at hand. We have found only the papers of Le Chatelier† and Seliwanow.‡ The former gives as a preliminary result for a 10 per cent alloy between 0° and 1000° an expansion coefficient some 30 per cent higher than 0°–100°; the latter for platinum 0°–1650° gives a result only 11 per cent higher than at the lower temperatures. The temperature measurements is however, in the latter case, uncertain.

Table IX shows the values for the ice point (H_0) and coefficient of expansion (α) to be nearly constant. After the last heating, made with the first gas filling, a considerable increase in H_0 will be noticed which, however, is solely due to the fact that the temperature was carried for the first time up to 1300°. Afterward when the bulb had been evacuated and freshly filled at 1300° a second heating to the same point showed no change in the ice point whatever.

In order to accomplish this result great care is necessary in the choice of the material used in the construction of the oven. We include herewith ice points from an earlier series of observations where a sudden and sharp increase occurred which could be foreseen during the progress of the heating. The outer mantle of the then new oven consisted of sun-dried

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* Benoît, Trav. et Mém. du Bur. internat., vi, 190, 1888.
† Le Chatelier, C. R., cviii, 1096, 1889.
‡ Seliwanow, Journ. d. russ. phys. Ges., xxiii, II, 152, 1891.

(unburned) clay containing organic substances which burned when the bulb reached a temperature of 1000°, as could be readily detected by the odor in the room. The air thermometer at once began to go up and continued doing so for some minutes, though the thermo-element in the oven showed the temperature inside to be actually falling. This plainly showed that the gases of combustion were penetrating into the bulb in spite of an excess of pressure within of a full atmosphere. Further observations were suspended for the time and the oven allowed to cool, when the ice point was found to have risen $4{\cdot}46^{mm}$.

The zero points for the series follow:

Bulb freshly filled....................	$296{\cdot}67^{mm}$ Hg.
After heating to 1085°................	296·66 "
After standing undisturbed for 18 days	296·66 "
After heating as above described.....	301·12 "

7. *Conclusion.*

We have then as a result of the foregoing investigation two curves based upon the thermo-elements T_1 and T_2 respectively. If we compare these we shall obtain the difference between the temperature scale measured with porcelain bulbs and that secured from the platin-iridium bulb. In Table XI this difference Δ is given in microvolts and in degrees.

TABLE XI.

	T_2-T_1 Microvolts.	Δ Microvolts.	Δ Degrees.
500°	93	4	0·4°
550	101	1	0·1
600	107	1	0·1
650	115	1	0·1
700	122	3	0·3
750	130	4	0·4
800	138	8	0·7
850	147	13	1·2
900	156	20	1·8
950	165	28	2·4
1000	174	39	3·3
1050	183	55	4·6
1100	192	77	6·4
1150	201	105	8·5

The difference, as will be seen, always has the same sign, that is, the scale founded upon the porcelain values always gives a somewhat higher value for the temperature than the other. In the lower part of the scale the Δ chances to be smaller than the errors of observation; even in the vicinity of 1000° it is not higher than the possible error in the value assumed for the coefficient of expansion of the bulb (3β). An increase of 10 per cent in 3β causes an increase of 1·5° at 1000° for the porcelain scale and 3·2° for the platinum. Above 1000° the values of Δ increase rapidly. The values obtained from the platinum bulb must be accorded the preference, however, not only on account of the constancy of ice point and coefficient of expansion but on account of the much reduced error due to the unheated space.

It is not impossible that at high temperatures a vapor is developed in the porcelain bulbs, in fact in the bulbs containing glazing this could quite naturally take place.

Our purpose is to continue the observations with the platin-iridium bulb to still higher temperatures and to investigate a second similar bulb which the firm of Heräus has kindly placed at our disposal. The coefficient of expansion (3β) and the effect of pressure at the higher temperatures will also be determined.

Dr. Hans Usener, who undertook this investigation with us and carried on for a considerable time the thermo-electrical observations, left it to accept a position at the German Government Torpedo Station at Kiel.

Charlottenburg, June, 1899.

Art. XIX.—*On the Flicker Photometer;* by Ogden N. Rood, Professor of Physics in Columbia University.

In the September number of this Journal, 1893, I published an account of "A photometric method which is independent of color," the principle being, that when two colored surfaces are presented in rapid succession to the eye, the resulting flicker vanishes when they have the same luminosity. My experiments were afterward repeated and amplified by Dr. F. L. Tufts, who obtained confirmatory results.* In my paper I also remarked, that "there does not seem to be any reason why this process, with the aid of well known optical devices, should not be applied to ordinary photometric work, or to such as is carried on in the interior of the observing telescope of a spectroscope."

In 1896 Prof. F. P. Whitman devised a photometer with a revolving card-board disc, in which the proposed flicker method was utilized, and which gave satisfactory results.† On Nov. 17th, 1896, I read a paper before the National Academy of Sciences, in which were described four methods in which the flicker process could be employed photometrically: (*a*) by the use of convex or concave lenses oscillating at proper rates, (*b*) by a vibrating plane mirror, (*c*) by a revolving glass prism of small angle, (*d*) by a revolving plane mirror set excentrically on its axis. Apparatus embodying these ideas had at that time been constructed and used by me. In 1897 I constructed a complete photometer, using an oscillating convex cylindrical lens, and made many measurements with it. The instrument was briefly described in Science, June 3d, 1898, and a week later, in the same periodical, appeared a short account of some quantitative observations made with it on color-blindness. Since that time, the convex cylindrical lens has been replaced advantageously by one that is *concave*, and the paper prism previously used by one of plaster of Paris. The field has also been very much contracted, and other improvements introduced, particularly in the matter of uniformity of rate of oscillation and choice of such rate.

The general idea of the photometer is that the differently colored beams of light traversing its axis should illuminate the two surfaces of a rectangular prism, P, facing the eye, and that by the oscillations of a cylindrical concave lens, C, in front of the prism, its illuminated surfaces should alternately and in rapid succession be presented to the eye. One incandescent lamp, L′, remains stationary; the other is moved by the observer till all flicker disappears, when a reading is registered on a fillet of paper, which is not inspected by the observer till the conclusion of the operation. In many of my experiments the light was colored by transmission through plates of colored glass, G, G′, and was almost spectral in hue. On a strip of board, B, 8 c. broad and 3·3 m. in length, graduated in centimeters, the incandescent lamps are placed, suitable guides keeping them in the axis of the instrument. One of the lamps can be moved by a long slender strip of wood, S, to which is attached a fillet of paper to receive the observations, which are impressed on it by a pin-point suitably arranged. The other lamp is stationed where in each case it is found desirable.

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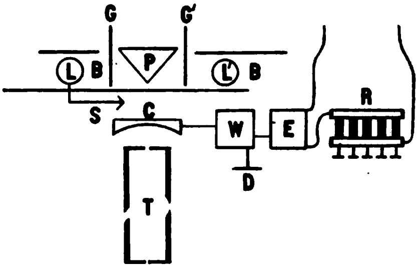
* Transactions of the New York Academy of Sciences, xvi, 190–212, April, 1897.

† Physical Review, vol. iii, No. 16, Jan.–Feb., 1896.



The prism, P, is fastened on the center of the long board at the common zero point of the two sets of graduations, and the most important thing about it is, that its two faces should meet in an invisible line; otherwise the juncture, not being illuminated, appears in the field as a vertical black line, and this will of itself furnish a faint flicker, that becomes apparent after the flicker from the faces of the prism has disappeared. Good prisms, free from this defect, can be made by casting plaster of Paris in a mould composed of glass plates, suitably ground on their edges. These plates can be removed from the plaster by the gentle heat of a spirit lamp, without damage to the dividing line between the faces of the still moist prism. When heat is applied, the plates fall off of themselves. With paper prisms, however well prepared, it is impossible entirely to get rid of the black dividing line, and the observer is obliged to rely on obtaining a minimum flicker.

With the above object still in view, it is best to use a *concave* cylindrical oscillating lens, which diminishes still further the bad effects of any want of perfection in the prism; that employed by me had a focus of 13 centimeters; its outline was square, the sides being 4 centimeters in length. It was placed parallel to the line where the prism faces meet and also parallel to the axis of the instrument. Its distance from the prism was 16 centimeters.

The observing tube, T, had a length of 21 and a diameter of 4 centimeters. It was placed at right angles, both to the vertical axis of the prism and to the axis of the photometer. Both ends of it were furnished with diaphragms pierced by apertures 5^{mm} in diameter; the end next to the cylindrical lens should be brought as near to the lens as practicable. The visible field thus obtained is rather small, but quite sufficient, larger fields having been found to give inferior results, particularly in the hands of untrained observers.

In the apparatus as at present arranged a small electromotor, E, is used to give the cylindrical lens the proper oscillatory movement through the intervention of a train of toothed wheels, W. The speed of the motor is regulated in the following way: a current is employed more than sufficient to drive the motor at proper speed, and the strength of this current is reduced by the introduction of a variable resistance, R, composed of five glass tubes, each of which is 13 centimeters in length with an internal diameter of 2 centimeters. The tubes are filled with a mixture of coarse graphite and asbestos, which can be more or less compressed by the aid of five screws provided with plungers. As each tube carries only the fifth of the current, the rise in temperature is inconsiderable. The idea of employing the mixture for a variable resistance was borrowed from Dr. Hallock. In this way the speed of the oscillating lens can be regulated and kept constant for a long time. For the sake of convenience, a rotating card-board disc, D, is attached to W, and provided with a proper number of black and white sectors. Its appearance enables the observer to judge whether the proper rate of speed is being employed.

The photometer is most sensitive, that is the flicker is strongest, when the rate of oscillation is such that the two colored surfaces in the field are just fairly blended by the movement of the lens, and cannot be distinguished separately. The rate of lens oscillation usually employed has been about sixteen per second, more or less. When the illumination is feeble, low rates are preferable; when it is strong, higher rates are better, and some persons seem to have a general preference for rather high rates, which while diminishing the sensitiveness somewhat, also abolish flicker due to imperfection in the prism.

Finally, movable screens of black pasteboard are arranged around the prism, observing tube, and partially around the head of the observer, in such a way that all extraneous light is cut off.

The mode of making the observations is much the same as with ordinary photometers; by a preliminary experiment the position of flicker disappearance is approximately ascertained, and then the moving lamp is displaced till a distinct flicker is noticed; it is then brought up till this disappears, and the operation repeated in the reversed sense, both observations being recorded. From time to time wider excursions are made, to avoid the danger of "falling into a rut." Two fiducial marks are finally impressed on the fillet of paper, which is removed and read with a lens and millimeter scale. Persons trained in laboratory work usually obtain good results in their first trials; this was the case with Miss Furness, Dr. Dennett, Professor Hallock and some of the laboratory assistants. In other cases a certain amount of training was found necessary, which seemed to be due to the fact that the attention of the observer was allowed to wander from flicker-perception to color-perception, and to the changes in it due to the position of the movable lamp. With the small field now employed, there is no eye-fatigue, except that incident on looking steadily into any kind of tube for some minutes.

In order to furnish an idea of the degree of accuracy attainable, I give below sets of results obtained by myself when using three pairs of colors, red and blue, red and green, green and blue. The colored light was furnished by colored glass, and was to all appearance spectral in its purity. One face of the prism being illuminated with red light from the stationary lamp, the other received violet-blue light from the movable lamp, which was adjusted till the flicker vanished, and its mean distance from the edge of the prism obtained, ten observations being made. For certain purposes this operation was repeated on seven different days. Taking the mean distance of all seven results as correct, and as corresponding when squared to 100 per cent, I calculated the deviations from this in each of the seven cases in percentages.

Red and Blue.			Red and Green.			Blue and Green.		
		Diff.			Diff.			Diff.
Dec.	13	−0·26	Feb.	2	−0·89	Jan.	5	+3·5
"	16	+1·74	"	3	+2·60	"	16	+0·01
Jan.	5	+0·4	"	11	+1·10	"	17	−1·91
"	13	−0·26	"	15	−1·69	"	18	+0·84
"	16	−1·57	"	17	−0·35	"	24	−1·26
"	17	−0·26	"	20	−1·95	"	25	−1·26
"	18	+0·3	March	1	+1·29			

Similar results are also given above for the pair red-green and green-blue. No account is taken of possible variations in the relative intensity of the two lamps, since such variation would at least not have tended to increase the accuracy of the results.

In order to exhibit the working of the instrument in the hands of other persons, I give below results obtained by six good observers, with each of whom I compared my own color-vision; they contain an element which furnishes a rather severe test of the correctness of the whole procedure that is entirely wanting in the tables above given. Each of the six persons was successively, for the time being, assumed to have standard color vision, viz: their perception of red, green and blue was taken as 100 in each case, and I determined my variations from it, both of us using the pairs, red-blue, red-green, and blue-green. In this mode of procedure it was possible to obtain two values for my perception of green as compared with theirs, a direct one founded on our joint experiment on the pair red-green, and an indirect one derived from our joint observations on the pair green-blue, my value for blue having first been obtained by a third joint experiment on the pair red-blue. If all the readings obtained by the person used as a standard and by the one undergoing examination are correct, then the direct and the indirect value for the green should coincide. Attention is again called to the fact that the indirect value is obtained by the use of an *intermediate* color. Below is a table showing the variations in percentages between these direct and indirect values of the green.

Dr. Dennett	−0·32	Mr. Parker	+1·77
Miss Furness	−1·04	Dr. Tufts	+3·17
Dr. Hallock	+0·41	Mr. Wade	−0·69

The general conclusion to be drawn from the numerical results given in this paper would seem to be, that the accuracy attainable with the flicker photometer, as at present constructed and using light of different colors almost spectral in hue, is about the same as with ordinary photometers using plain white light, or light of exactly the same color.

New York, May 8th, 1899.

ART. XX.—*A Quantitative Investigation of the Coherer;*
by A. TROWBRIDGE.

SINCE the very remarkable success of G. Marconi in the field of wireless telegraphy, a renewed interest has been felt by physicists in the coherer, the apparatus devised by Branley which has made wireless telegraphy possible.

Besides the original paper* of Branley there have been a number of communications on the subject of coherer action; in particular those of Dorn† and Aschkinass,‡ which have thrown much light on the subject. As yet, however, the experimental data are not complete enough for a perfectly satisfactory theory of coherer action to be formed, those already existing being seemingly inadequate to explain all the observed phenomena.

Even if we do not know just what takes place in the coherer itself, we know that the cause of the fall in resistance is primarily an electro-magnetic disturbance in the space surrounding the coherer. This disturbance will induce a static wave in a conductor whose direction in space coincides with the direction of the lines of electric force from the source of the electromagnetic disturbance. If this static wave is the cause of the lowering of the resistance of the coherer, then a static discharge from a Leyden jar, or electrophorus, through the coherer, should produce a like effect. This conclusion was verified by Professor Henry S. Carhart and myself while we were engaged a few months ago in testing the sensibility of coherers for telegraphic purposes. If this conclusion is warranted, then on the nature of the discharge and the quantity of electricity which goes through the coherer should depend the fall of resistance of the latter.

The present paper has to deal with the lowering of the resistance as a function of the quantity of electricity discharged through and the difference of potential on opposite sides of the coherer.

In order to test the supposed relation between quantity of electricity discharged and the fall of resistance in the coherer, I adopted the following arrangement.

By means of a charge and discharge key, a subdivided condenser could be charged from a large storage battery, the electromotive force of which could be varied at will from 2 to 70 volts, and then discharged through the coherer. The capacity at my disposal could be varied from 3·2 microfarad to 0·05 microfarad, and this range, taken together with that of the storage battery, made it possible to vary the product $CV = Q$, within a comparatively large range, the upper limit of which, however, was only 224 micro-coulombs.

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* Compt. Rendus, cxi.

† Wied. Ann., lxvi, p. 146.

‡ Wied. Ann., lxvi, p. 284.

For the purpose of measuring the fall of resistance, a branch circuit containing a single storage cell (E. M. F.=2 volts) and a milli-ammeter was connected to the ends of the coherer. The limit of accuracy in reading the milli-ammeter was 0·001 ampere.

With a coherer of the type described by Marconi, I found, as I expected, an increase in conductivity with an increase in quantity of electricity sent through the coherer; however on increasing Q beyond a certain point, the corresponding increase in conductivity was very small; for the coherer in question, for example, the increase in conductivity was very rapid on increasing Q up to about 15 micro-coulombs, but beyond this point, doubling the quantity only produced a fractional change in the conductivity. It seemed as if the 15 micro-coulombs were enough to produce all, or nearly all, the lowering possible for the coherer in question and for the given charging potential (a point I will explain presently).

As the results obtained with the above mentioned coherer were not concordant enough for quantitative work, I adopted another type which I have since seen described in a paper by Branley,* in which he claims that it is more sensitive than the older form.

The coherer I used consisted of 21 bicycle pedal balls (diameter 3^{mm}) mounted in a horizontal glass tube of about the same bore, the end balls being soldered to lead-wires and the tube being provided with a device for adjusting the pressure of contact between the balls. The normal resistance of this coherer was about 2000 ohms, care being taken always to return to about this resistance by tapping the tube and adjusting the pressure before an observation was taken on the fall of resistance due to the discharge of the condenser. M. Branley used hard steel balls 12^{mm} in diameter—those first used by me were $9·5^{mm}$ in diameter, but I found the smaller ones finally used to be much better suited to my purpose, at least, and I should judge that this would also hold true for telegraphic purposes.

However, I made no attempt at long-distance telegraphy with my coherer, having only satisfied myself that, at short range, the ball coherer behaved in all respects like a filing coherer.

The method of observation was the following: With a given charging potential the capacity was varied through the limits above mentioned: for each capacity the mean of about 20 observations was taken on the lower limit of resistance attained by the coherer on discharging the capacity through it; this resistance being indirectly obtained by Ohm's law from the readings of the milli-ammeter.

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* Comptes Rendus, No. 18, May, 1899.

As I have mentioned above, the upper limit, or normal resistance of the coherer was arranged to have a uniform value of about 2000 ohms.

Next, the charging potential was given another value and a like set of observations taken, and so on through the range of the charging potential.

It was at once evident that the lower limits of the resistance was not the simple function of the quantity of electricity sent through the coherer that I had expected. If this had been the case, I should have found the lower limit of the resistance the same for the cases $Q = C_1V_1 = C_2V_2 = C_3V_3$, etc. = constant. From my observations this was distinctly *not* the case.

I found that for Q = constant, the larger the charging potential—and hence the smaller the capacity—the lower was the final resistance or the greater the conductivity of the coherer after the discharge.

I have given the results of my observations on the ball coherer in curves 1 and 2. A table of the numerical values I obtained I have not given, since it would be of little theoretical import, as it would hold only for the coherer I used. The form of the curves given should, I believe, be similar for all coherers.

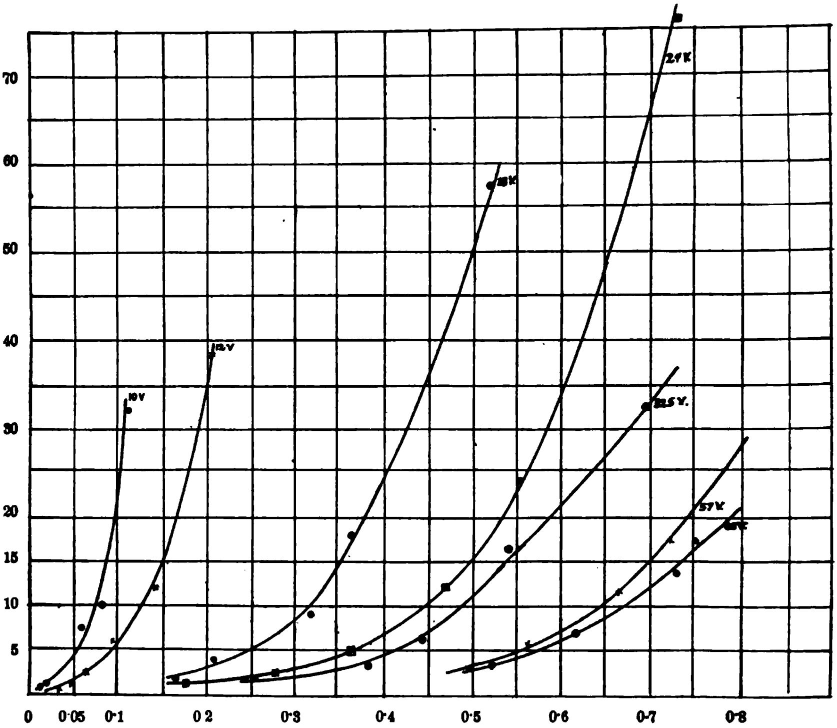
In curve 1, the abscissas represent the reciprocals of the lower limit of resistance of the coherer, or the conductivity; the ordinates, the quantity of electricity sent through. The seven different curves represent the change in conductivity as a function of the quantity for the seven different charging potentials used; the indices $V=10$, 12, 18, etc., denoting these potentials.

As will be seen, all the curves tend in a general way, as they should, towards a point on the conductivity axis, very near the origin; a point which would denote the reciprocal of 2000 ohms, the normal resistance. Also it is clear that the greater the charging potential, the more rapid the rise of the conductivity per unit increase in quantity discharged.

I was unable, with the coherer used, to get coherer action when the charging potential of 8 volts and under was used. This point is brought out by the set of curves No. 2, in which the abscissas are the same as in curves No. 1, while the ordinates represent charging potentials. All the curves Q = constant cut the ordinate axis at a point $V = 8{\cdot}75$ volts. This is, so to speak, the critical voltage for the coherer under examination. Unless a potential difference between the terminals of the coherer of at least this value is produced by the electromagnetic disturbance, no coherer action will take place.

Probably every coherer has a critical value of the potential difference peculiar to itself, a coherer with a low value being preferable for telegraphic purposes. Owing to lack of time I have not been able to experiment with more than one coherer.

1



When we inquire into the nature of the discharge through the coherer which produces a lowering of resistance, the question arises as to whether or not it is of an oscillatory character.

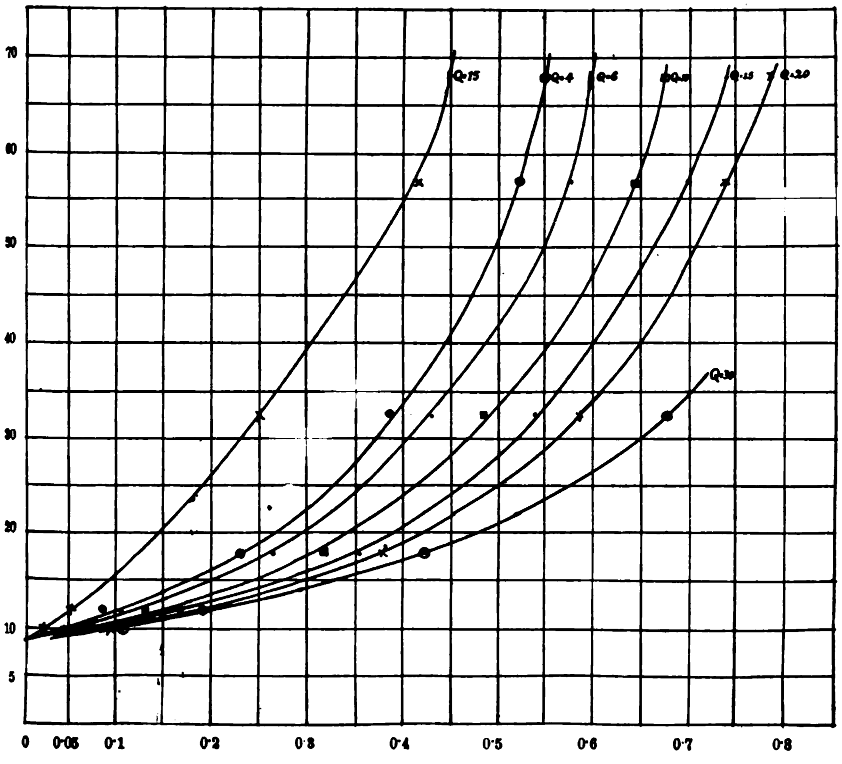
From the theory of the oscillatory discharge of a condenser, we have a term

$$\sqrt{r^2 - 4\frac{L}{C}}$$

entering into the expression for the current strength I, where r is the resistance of the discharge circuit and L and C respectively the self-induction and capacity. If $r^2 < 4\frac{L}{C}$, an imaginary quantity enters into the expression for I, this is the condition for a periodic discharge. If, on the other hand, $r^2 > 4\frac{L}{C}$, we have an aperiodic discharge.

Under the conditions present in my investigation, the latter case was certainly realized, for r normal was 2000 ohms, C from 3·2–0·05 microfarad and L certainly very small, say less than 0·01 quadrant.

2



$$r^2 = 4\cdot10^6 \text{ ohm} = 4\cdot10^{24} \text{ cm. sec.}^{-1}$$
$$C = 0\cdot05 \text{ microfarad} = 5\cdot10^{-17} \text{ cm.}^{-1} \text{ sec.}^2$$
$$L = \text{say } 0\cdot01 \text{ quadrant} = 10\cdot10^6$$
$$4\frac{L}{C} = 4\frac{10\cdot10^6}{5\cdot10^{-17}} = 8\cdot10^{23} < [4\cdot10^{24} = r^2]$$

As L is certainly less than the value here assumed, the discharge circuit being a short straight copper wire, it is evident that $r^2 > 4\frac{L}{C}$, or that the discharge which affects the lowering of resistance in this investigation was aperiodic. I tested this point experimentally in the following manner: the condenser was removed and the lead-wires from the storage battery to the ends of the coherer were provided with a key and a thin $\frac{1}{10}$ ampere fuse-wire in series. When the key was closed a steady current flowed through the coherer—the voltage of the storage battery was varied through a range of from 8–70 volts, and the lowering of the resistance of the coherer was again found to vary as the voltage. Owing to the element of time entering into the problem (the time elapsing from the closing of the key to the blowing out of the fuse), it was not possible to make quantitative observations on the fall of resistance. It was evident, however, that a steady current did produce this drop in resistance, that the drop was greater the greater the electromotive force of the storage battery, and further, as I had before noted, that for an electromotive force less than from 8–10 volts no coherer action took place.

Now we can regard the coherer with its vertical wire and earth connection, as it is used by Marconi, as part of the discharged circuit of a condenser whose plates are the vertical wire and the earth. A certain potential difference between vertical wire and earth is caused by the electromagnetic waves sent out from the Herz oscillator; this potential and the capacity of the vertical wire—earth condenser determine the quantity of electricity which is discharged through the coherer in the form of an aperiodic impulse and which produces the lowering in resistance necessary to wireless telegraphy. The potential difference on opposite sides of the coherer must be an inverse function of the distance between sending and receiving stations; if this distance is small, the potential difference being above what I have called the critical potential for the coherer used, if we increase the capacity of the vertical wire we shall increase the fall in resistance of the coherer, but if the distance is so great that the potential is at about its critical value, then an increase in capacity would lower the potential and so diminish or destroy the sensibility of the coherer.

This would explain Marconi's statement that at short distances a capacity consisting of a cubical tin box mounted at the top of the vertical wire, increased the sensibility of the coherer, but that he found it advisable to omit this capacity when telegraphing long distances.

It is also evident that one precaution must be taken when using a very sensitive coherer for wireless telegraphy. Since a steady current will produce coherer action if the potential difference between the ends of the coherer exceed what I have called the critical voltage, and since the lower this critical value is, the more sensitive will be the coherer for long-distance work, care must be taken that the electromotive force of the battery which operates the relay in Marconi's arrangement, shall have a value less than the critical value for the coherer used.

If an electromotive force of about the critical value is used, we might expect to notice a confusion of the signals from the sending station due to the local circuit through the coherer producing an independent and quite irregular lowering of the resistance.

Everyone who has attempted wireless telegraphy has probably been annoyed by extra "clicks" of the instrument. I believe it is in many cases attributable to the cause just mentioned; in which case it could be done away with by so choosing critical potential of coherer, electromotive force of battery in coherer circuit, and sensibility of the relay, that the first should be higher than the second, while the third should be great enough to permit of a small absolute value of the other two.

In conclusion, I should like to take this opportunity to express my thanks to my colleague, Dr. Karl Guthe, for his kindly interest in the present investigation, and for numerous helpful suggestions.

Physical Laboratory of the University of Michigan, June, 1899.

ART. XXI.—*The Double Ammonium Phosphates of Beryllium, Zinc, and Cadmium in Analysis;* by MARTHA AUSTIN.

[Contribution from the Kent Chemical Laboratory of Yale University—LXXXVI.]

IT has been shown* that the composition of the phosphate of manganese thrown down by microcosmic salt from the solution of a pure manganous salt contains more manganese than belongs to the ideal ammonium manganese phosphate NH_4MnPO_4; and, further, that by acting with ammonium chloride in proper proportion the phosphate of manganese thrown down by microcosmic salt may be completely converted to the ideal ammonium manganese phosphate. Ammonium chloride, likewise, in the case of magnesium phosphate† tends to cause the replacement of the metal by ammonia. Indeed, the replacement here is readily carried so far beyond the point corresponding to the normal ammonium magnesium phosphate, NH_4MgPO_4, that the tendency to form a salt richer in ammonia and poorer in magnesium—perhaps something like $Mg(NH_4)_4(PO_4)_2$—must be recognized.

These facts suggested an investigation into the constitution of certain other ammonium phosphates with reference to their utility in analytical processes. Of the elements of Mendeléeff's second group, beryllium, magnesium, zinc, cadmium and mercury are capable of yielding double ammonium phosphates, while no such compounds of calcium, strontium and barium have been described. The solubility in ammonia of the double ammonium phosphates of the elements of the former category appears to increase as the elements of which they are compounds are removed in the series from the beryllium, and, while the same is true of the simple phosphates of members of the latter category, the extent of such solvent action is slight comparatively. According to the work recorded in the literature, calcium, barium, and strontium form individually a neutral tribasic phosphate or acid phosphates of greater or less degree of acidity according to the conditions of precipitation. In my experience where salts of these elements were precipitated either with ammonium phosphate or microcosmic salt in presence of varying amounts of ammonium chloride, or ammonia, or both, only the recognized phosphates were obtained. The effect of ammonium salts in presence of ammonia seemed to promote the formation of the tribasic salt in the case of calcium and strontium; barium tends to form the barium acid phosphate almost exclusively even in the presence of ammonium salts and free ammonia. No double ammonium phosphate of either calcium, strontium, or barium was produced under any condition. As is well known, mercury does form an ammonium mercury phosphate, but the salt is soluble to so great a degree in ammonia, ammonium chloride, and even in the precipitant itself, that nothing of any value for analytical work seemed likely to come from its study.

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* This Journal, vol. vi, 233.

† This Journal, vol. vii, 187.

The Ammonium Beryllium Phosphate.

The ammonium beryllium phosphate has been described by Roessler* as a crystalline salt produced by boiling some time in ammoniacal solution the phosphate precipitated by ammonium phosphate, though the best results of this treatment failed to yield the ideal constitution of this salt, NH_4BePO_4. This same precipitate can not be obtained, Roessler further states, by using a sodium salt as the precipitant. In order to follow out this work of Roessler, a solution of beryllium chloride for use was prepared as follows: The pure beryllium chloride of commerce was dissolved in as little water as possible and treated for the precipitation of aluminum by etherial hydrochloric acid.† After filtering and evaporating from the filtrate the ether and a part of the hydrochloric acid, the beryllium was precipitated with ammonia, filtered to remove any members of the magnesium group, and washed free from ammonium chloride. The larger part of the precipitate was dissolved in hydrochloric acid in slight excess, and boiled with the reserved portion. After filtering, the solution was diluted to definite volume and standardized by precipitating measured portions of the solution with ammonia, filtering on asbestos under pressure in a perforated platinum crucible, igniting the residue and weighing as the oxide. The results recorded in section A of the following table were obtained by precipitating definite volumes of the pure solution of beryllium chloride with ammonium phosphate in a platinum dish, dissolving the precipitate in hydrochloric acid in faint excess, and while hot precipitating slowly with dilute ammonia, boiling (while the solution was kept distinctly ammoniacal) until the flocky precipitate was entirely converted to a fine, powdery, semi-crystalline, rapidly subsiding mass. A quarter to a half hour is necessary under the most favorable conditions to cause this conversion. After cooling, the precipitate was filtered off on asbestos under pressure in a perforated platinum crucible, washed carefully with distilled water, dried, ignited and weighed. The filtrate was tested for beryllium by boiling with ammonia. None was found in these cases, nor in any of the following work. Faint traces of chloride were found in the residues after ignition after dissolving in nitric acid and testing with silver nitrate.

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* Fresenius, Zeitschrift für analyt. Chemie, 1878, 148.

† This Journal, vol. iv, 111.

The results are in every case in excess of the theory for the pyrophosphate derived by ignition of the ammonium beryllium phosphate, possibly because the ammonium chloride present may have a tendency to form a salt too rich in ammonium (as was shown to be the case with the magnesium salt), consequently giving too much phosphoric acid in the ignited residue; or, because of inclusion of the chloride and phosphoric acid. It might reasonably be expected that some phosphoric acid may be held since a trace of chloride was found. Either or both of these substances may have been held mechanically, or in combination.

It was found that by boiling for some time the solution of beryllium chloride with microcosmic salt—(6) section B of the table—precipitating in the same manner as when ammonium phosphate was used—that the same sort of powdery mass remained as was obtained by the ammonium phosphate. The residue being tested for sodium according to the method brought out by Kreider and Breckenridge,* showed sodium present to the amount of 0·0062 grams reckoned as sodium phosphate. It may be reasonably supposed that the presence of the sodium was due to one of two causes, inclusion of the soluble phosphate, or to a tendency on the part of the beryllium to form an ammonium† sodium beryllium phosphate or a sodium‡ beryllium phosphate, both of which are known to exist. Long boiling of the precipitates is tedious, and, unless great care is taken, may involve small losses of material; hence if the same results could be obtained with less boiling such treatment would be decidedly advantageous. The results in section C of the table were obtained by adding microcosmic salt to the hot solutions of the chloride, boiling five minutes, cooling, filtering off on an ashless filter—because of the flocky condition of the precipitate—treating as usual before igniting the residue in a platinum crucible. The results compare well with those obtained by long boiling of the precipitated beryllium—although all are in excess of the theory. That ammonium chloride here, as in cases above, has a marked effect in changing the constitution of the phosphate precipitated by microcosmic salt is not readily seen. It is obvious that the presence of an excess of the soluble phosphate is essential to precipitate the beryllium as the double ammonium phosphate from the results recorded in section D of the table, where, after the precipitate of beryllium phosphate had subsided and the supernatant liquid had been poured off, the precipitate dissolved in hydrochloric acid was brought down again at the boiling temperature with ammonia either alone or in presence of ammonium chloride. The results obtained show that the salt approaches the constitution of the tribasic phosphate, when it is precipitated in presence of a faint excess of phosphoric acid, even though ammonium chloride in large amount be present.

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* This Journal, vol. ii, 263.

† Persoz, Liebig's Annalen, lxv, 174; Atterberg, Bulletin d. l. Soc. chim. d Paris, xxiv, 358.

‡ Scheffer, Liebig's Annalen, cix, 144.

Table I.

	$Be_2P_2O_7$ corresponding to $BeCl_2$.			$Be_3P_2O_8$ corresponding to $BeCl_2$.				
	Taken. grm.	Found. grm.	Error. grm.	Taken. grm.	Found. grm.	Error. grm.	$(NH_4)_2PO_4$. grm.	NH_4Cl grm.
				A.				
(1)	0·3578	0·3613	0·0035 +				2	--
(2)	0·3578	0·3808	0·0230 +				2	--
(3)	0·3578	0·3707	0·0129 +				2	--
(4)	0·3578	0·3640	0·0062 +				2	--
(5)	0·3578	0·3680	0·0102 +				2	30
				B.				
							$HNaNH_4PO_4.4H_2O$	
(6)	0·3578	0·3697	0·0119 +					
				C.				
(7)	0·3578	0·3618	0·0040 +				1·2	--
(8)	0·3578	0·3680	0·0102 +				1·2	--
(9)	0·3578	0·3729	0·0151 +				1·2	10
(10)	0·3578	0·3631	0·0053 +				1·2	60
				D.				
(11)				0·2700	0·2589	0·0111 —	0·5	----
(12)				0·2700	0·2989	0·0289 +	0·5	—10
(13)				0·2700	0·2936	0·0236 +	0·5	5–60
(14)				0·2700	0·2507	0·0193 —	0·5	—60

From the work described it is clear that the ammonium beryllium phosphate is not obtained in ideal condition by precipitating a solution of the chloride with ammonium phosphate. Roessler's own results were likewise only approximately correct, as he states. It is also plain that hydrogen sodium ammonium phosphate precipitates the ammonium beryllium phosphate in a condition as nearly ideal as does the ammonium phosphate, while the effect of the ammonium chloride in either case is not marked in producing a phosphate containing ammonia. Of most importance in obtaining the ammonium salt is an excess of the soluble phosphate, for when the amount of the precipitant is reduced to a little more than the theoretical amount the condition of the phosphate coincides almost exactly with the theory for the tribasic phosphate, even though a large excess of ammonium chloride be present. When there is an abundance of the precipitant the results are all in excess of the theory, which may be accounted for on the supposition that foreign material is included—the chloride of ammonia and the soluble phosphate—to a greater or less extent by the precipitate. The formation of a phosphate of beryllium containing too much ammonia and phosphoric acid, or, in case of the precipitations by microcosmic salt or sodium by the formation of a sodium ammonium beryllium phosphate and sodium beryllium phosphate (known salts) is not definitely proved.

The Ammonium Zinc Phosphate.

Debray,* Bette† and Heintz‡ separately found that ammonium zinc phosphate is formed by boiling a solution of zinc sulphate with ammonium phosphate. This salt was investigated later by A. Guyard (Hugo Tamm),§ who found that if to a solution of a zinc salt of an organic or a mineral acid supersaturated with ammonia until all the zinc oxide is dissolved and made faintly acid with hydrochloric acid, sodium phosphate be added, a flocky precipitate resulted, which on being kept near the boiling point for some seconds was converted to crystalline zinc ammonium phosphate, which filtered readily and was washed free from impurities with the greatest facility. He found that all the zinc in solution was thrown down as the ammonium zinc phosphate, which on ignition yielded the zinc pyrophosphate. With care in handling this process to avoid an excess of the precipitant, and the presence of sodium and potassium salts (on account of the danger of occlusion) the precipitation of the ammonium zinc phosphate, ignition, and weighing as the pyrophosphate made, Guyard believed, an ideal process for the estimation of zinc. Although there was slight solubility of the salt, it made an insignificant loss when the process was handled properly. Acids present, or certain alkalies to any great extent, increased the solubility of the salt so much that the loss became appreciable. Another source of error was to Guyard's mind loss of zinc during the ignition of the zinc ammonium phosphate with the paper on which the precipitate had been collected. Garrigues‖ found, in estimating zinc in a practical way, that this process advocated by Guyard gives in solutions of zinc free from salts of all metals, even alkaline salts—solutions that from previous steps in analysis, however, must have contained ammonium chloride in large amount—as satisfactory results as Guyard claimed for it.

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* Comptes Rendus, lix, 40.

† Liebig's Annalen, xv, 129.

‡ Liebig's Annalen, cxliii, 156.

§ Chemical News, xxiv, 148.

‖ Jour. Am. Chem. Soc., xix, 936.

Garrigues' method of procedure was to add acid diammonium phosphate to a warm solution of zinc exactly neutralized with either hydrochloric acid or ammonia so that the weights of zinc ammonium phosphate and that of the diammonium phosphate added should be as one to five respectively, to heat until the flocky precipitate becomes crystalline and subsides, filtering off on asbestos, drying at 100° C. and weighing preferably, although the residue may be ignited without loss, since the filtration is made on asbestos in a perforated crucible. Langmuir* modifies the method by destroying with dilute acetic acid any free ammonia that may be left in the solution after boiling.

In the work that follows, in which an attempt was made to show what precipitate is formed from a solution of zinc by the action of a soluble phosphate, also what effect ammonium chloride has upon the precipitate, a solution of zinc chloride prepared as detailed below was employed. The pure zinc chloride of commerce was treated with zinc carbonate, filtered and precipitated with ammonium sulphide. This precipitate was boiled in a slight excess of hydrochloric acid until all the hydrogen sulphide was removed, and then was precipitated with sodium carbonate. After washing carefully until all the chloride was removed, the greater part of the carbonate was dissolved in sulphuric acid in slight excess, boiled with the remaining portion of the carbonate and filtered. This solution diluted to definite volume was standardized as sulphate by evaporating the solution to dryness in a platinum crucible and heating the residue.† The heating is carried on safely by so placing the platinum crucible in a radiator (consisting of a crucible and a triangle) that the bottom of the platinum crucible was held about one centimeter above the bottom of the outside crucible. Constant weights were obtained in successive treatment with a few drops of sulphuric acid and heating over the radiator. The results obtained in this manner were a trifle higher, though in fair agreement (when the nature of the carbonate process is taken into consideration) with determinations of the zinc in the solutions as oxide after precipitating with sodium carbonate with the usual precautions, filtering off on asbestos under pressure in a perforated platinum crucible, washing with distilled water, drying and igniting. Results are given in Table II showing the amount of zinc sulphate found in five different portions each of forty cubic centimeters of the solution of zinc sulphate, and, for comparison, the results of determinations as zinc oxide by the carbonate processes are included.

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* Jour. Am. Chem. Soc, xxi, 115.

† Rose-Finkener Analytische Chemie, 6te Auflage, vol. ii, 117.

TABLE II.

$ZnSO_4$ found in 40^{cm^3} of solution. grm.	Mean value of ZnO corresponding to $ZnSO_4$ in 40^{cm^3} of solution. grm.	ZnO found in 40^{cm^3} of solution by precipitation as the carbonate. grm.
0·5386	0·2712	0·2691
0·5385		0.2685
0·5387		0·2711
0·5387		
0·5390		

Definite portions of the solution of zinc sulphate were carefully drawn from a burette into a platinum dish, heated and treated with ammonium phosphate until the solution turned red litmus paper blue. The whole was heated until the flocky precipitate became crystalline and fell to the bottom of the dish. The solution after standing as recorded in section A of the table was filtered off on asbestos under pressure in a perforated platinum crucible, and the precipitate was washed with distilled water, dried, ignited and weighed. The filtrate in each case, as in all following cases, was tested for zinc with sulphuretted hydrogen. The results recorded in section B of the table were obtained in the same manner as those of section A, with microcosmic salt substituted for the ammonium salt as the precipitant. The results are below the theory for the pyrophosphate, but no appreciable amount of zinc appeared in the filtrates. Neither ammonium phosphate nor ammonium sodium phosphate seems to precipitate the ideal ammonium zinc phosphate under these conditions; and the time of standing appears to be without effect.

The results recorded in section C were obtained by precipitating the warm solution of the zinc in presence of large amounts of ammonium chloride by adding microcosmic salt until the solution was alkaline to litmus. From these results it seems that the presence of ammonium chloride is essential for the conversion of the zinc phosphate precipitated by hydrogen sodium ammonium phosphate to the ammonium zinc salt. As a matter of fact the solutions employed by Guyard and those in which estimations are made by practical workers do contain ammonium chloride formed in previous steps of the analysis. The proportion of zinc to phosphate suggested by Garrigues—1 : 5—is the amount of soluble phosphate necessary to turn red litmus blue after the zinc is precipitated. In order to find out whether the presence of so large an amount of the soluble phosphate is necessary in presence of ammonium chloride, the solution of zinc sulphate was precipitated in presence of the necessary amount of ammonium chloride by the microcosmic salt, in small excess above the equivalent of the ammonium phosphate, and the solution was made just ammoniacal to litmus with a few drops of dilute ammonia both before and after heating to convert it to crystalline condition. Experiment (15) shows that precipitation is not complete under these conditions. The zinc left in the solution was precipitated at once as sulphide, and estimated as the oxide, after dissolving in hydrochloric acid and precipitating with sodium carbonate. In (16) of the table the first filtrate was treated with an excess of microcosmic salt, and boiled. Another portion of the ammonium zinc phosphate was precipitated, and was filtered off and estimated. No zinc was found by sulphuretted hydrogen in the second filtrate.

TABLE III.

$Zn_2P_2O_7$ corresponding to $ZnSO_4$. Taken. grm.	Found. grm.	Error. grm.	Error in terms of Zinc. grm.	$Zn_2P_2O_7$ corresponding to Zn left in the filtrate. grm.	$(NH_4)_3PO_4$. grm.	NH_4Cl. grm.	Time of standing. hours.
			A				
(1) 0·6355	0·6206	0·0149—	0·0060—	trace	3 13	....	1½
(2) 0·6355	0·6254	0·0101—	0·0040—	trace	3·13	....	16
(3) 0·6355	0·6300	0·0055—	0·0022—	trace	3·13	....	16
			B				
					$HNaNH_4PO_4 . 4H_2O$ grm.		
(4) 0 6355	0·6271	0·0084—	0·0034—	trace	4·47	0·5	1
(5) 0 6355	0·6256	0·0099—	0·0040—	none	4·47	0·5	20
			C				
(6) 0·6355	0·6285	0·0070—	0·0028—	none	4·47	10	½
(7) 0·6355	0·6304	0·0051—	0·0020—	none	4·47	10	¾
(8) 0·6355	0·6295	0·0060—	0·0024—	none	4·47	10	2½
(9) 0·6355	0·6335	0·0020—	0·0008—	none	4·47	10	16
(10) 0·6355	0·6381	0·0026 +	0·0010 +	none	4·47	20	½
(11) 0·6355	0·6379	0·0024 +	0·0009 +	none	4·47	20	2
(12) 0·6355	0·6386	0·0031 +	0·0012 +	none	4·47	20	½
(13) 0·6355	0·6393	0·0038 +	0·0014 +	none	4·47	20	½
(14) 0·6367	0·6355	0·0012 +	0·0005 +	none	4·47	30	16
			D				
(15) 0·6355	0·6172	0·0183—	0·0072—	0·0108	0·894	20	3
(16) 0·6355	I 0·6227 II 0·0040	0·0098—	0·0039—	none	I 0·894 II 3·576	20	½
			E				
(17) 0·6355	0·6270	0·0085—	0·0034—	none	4·47	....	3
(18) 0·6355	0 6125	0·0230—	0·0093—	0·0148	4·47	....	18
(19) 0·6355	0·6303	0·0052—	0·0021—	0·0020	4·47	10	18

From the results it seems obvious also that an excess of the soluble phosphate is necessary to complete the precipitation of the zinc as the ammonium zinc phosphate instead of partly ammonium zinc phosphate and partly tribasic phosphate.

In section E of the table are recorded results where the precipitation was made in presence of an excess of the precipitant either alone or in presence of ammonium chloride, the solution being made faintly acid to litmus with acetic acid, according to the manner in which Langmuir recommends to conduct the precipitation. All the results by the method are low. The condition of the ammonium zinc phosphate most nearly approximating to the ideal is obtained as shown in (9) to (14) by precipitating in presence of ammonium chloride in large amount. Microcosmic salt is added until the solution containing the ammonium salt is alkaline and the whole is heated until the mass subsides in crystalline condition. The amount of ammonium chloride should be twenty grams if the filtration is to be made as soon as the solution cools. One-half the amount will do if the liquid stands a number of hours. Larger amounts tend to give a salt too rich in ammonia. The time of standing seems to be a less important factor than either the excess of microcosmic salt or ammonium chloride.

The Ammonium Cadmium Phosphate.

According to S. Drewsen* the cadmium ammonium phosphate is precipitated by allowing a solution of cadmium sulphate to stand twenty-four hours with ammonium phosphate. It is very soluble both in acids and alkalies. No further preparation of this seems to have been recorded. For the work on this salt to be given below, made with reference to determining the constitution of the salt by hydrogen sodium ammonium phosphate, the effect of ammonium chloride in the precipitation, and the value of the salt for quantitative work, the solution of cadmium chloride employed was prepared as follows: A solution of cadmium sulphate acidulated with hydrochloric acid was precipitated with sulphuretted hydrogen, filtered and washed, and the precipitated sulphide was dissolved in hydrochloric acid and filtered from possible traces of copper and lead. The solution of the sulphide in hydrochloric acid was boiled until all the sulphuretted hydrogen was expelled, and filtered on asbestos in a perforated crucible of platinum under pressure. The cadmium in the filtrate precipitated with ammonium carbonate in excess was washed free from chloride, dissolved in hydrochloric acid and diluted to definite volume. It was standardized as oxide† after precipitating with sodium carbonate with the necessary precautions.

The standard solution of cadmium chloride was drawn carefully from a burette into a platinum dish, and, while hot, was precipitated by adding hydrogen sodium ammonium phosphate until the solution was alkaline to litmus. After heating until the solution became crystalline, the whole stood three hours in case of (1) of the table and sixteen hours in case of (2) and (3), before filtering. In experiments (4) to (12), inclusive, recorded in the table, precipitation was made in the same manner as in (1) to (3) in presence of varying amounts of ammonium chloride, and the precipitates were filtered after standing as stated below in the table. It is clear from the results that the cadmium separates out completely on long standing only. Moreover, the ideal condition of the ammonium cadmium phosphate is obtained only when an abundance of ammonium chloride is present; but large amounts of ammonium chloride dissolve this salt. In (14), where ammonia was added after precipitation was complete, the salt dissolved somewhat; also in (15), where the solution was left faintly acid with acetic acid, a large part of the salt was dissolved. These weights of cadmium dissolved in the filtrate were obtained by treating the filtrates with sulphuretted hydrogen, dissolving the sulphide in nitric acid, and weighing as oxide after precipitating with sodium carbonate.

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* Gmelin-Kraut, 6te Auflage, iii, 74.

† Browning, this Journal, xlvi, 280.

TABLE IV.

	$Cd_2P_2O_7$ corresponding to $CdCl_2$. Taken. grm.	Found. grm.	Error. grm.	Error in terms of Cadmium. grm.	$Cd_2P_2O_7$ corresponding to Cd found in the filtrate. grm.	$HNaNH_4PO_4 \cdot 4H_2O$. grm.	NH_4Cl. grm.	Time of standing. hrs.
(1)	0·6972	0·6201	0·0771—	0·0434—	0·0059	4·5	....	3
(2)	0·6972	0·6135	0·0837—	0·0471—	none	4·5	....	16
(3)	0·6972	0·6134	0·0838—	0·0471—	none	4·5	....	16
(4)	0·6972	0·6792	0·0180—	0·0101—	trace	4·5	1	16
(5)	0·6972	0·6831	0·0141—	0·0079—	0·0113	4·5	10	2
(6)	0·6972	0·6976	0·0004 +	0·0002 +	trace	4·5	10	16
(7)	0·6972	0·6969	0·0003—	0·0002—	trace	4·5	10	18
(8)	0·6972	0·6962	0·0010—	0·0006—	trace	4·5	10	16
(9)	0·6972	0·6891	0·0081—	0·0045—	0·0191	4·5	20	16
(10)	0·6972	0·6972	0·0000	0·0000	trace	4·5	20	16
(11)	0·6972	0·6942	0·0030—	0·0016—	trace	4·5	20	16
(12)	0·6972	0·6737	0·0235—	0·0132—	0·0304	4·5	30	16
(13)	0·6972	0·5655	0·1317—	0·0741—	0·1378	4·5	30	16
(14)	0·6972	0·6922	0·0050—	0·0023—	0·0088	4·5	10	16
(15)	0·6972	0·3209	0·3763—	0·2117—	0·2449	4·5	....	16

The ammonium cadmium phosphate is obtained in ideal condition by precipitating with microcosmic salt in presence of 10 grms. ammonium chloride in a total volume of 100^{cm} to 150^{cm}—shown in (6), (7) and (8)—filtering after standing some time. On drying and igniting the pyrophosphate is left. Very large amounts of ammonium chloride—30 grms.—dissolve the salt, and seem to tend to cause the formation of a phosphate too rich in ammonia. Either acid or ammonia in small amount dissolves the salt, as is shown in (14) and (15).

The results of this investigation as to the analytical application of the double ammonium phosphates of beryllium, zinc, and cadmium may be summarized briefly as follows: It is impossible to estimate beryllium with accuracy as the pyrophosphate obtained by igniting the double ammonium phosphate precipitated from beryllium solutions by microcosmic salt or ammonium phosphate in presence of ammonium chloride. In presence of the proper amount of ammonium chloride (10 grm. to 20 grm. in 100^{cm^3}–200^{cm^3} of liquid) zinc ammonium phosphate can be obtained in the ideal condition, which on ignition yields the pyrophosphate. This method may serve, therefore, for the accurate estimation of zinc.

Cadmium may be estimated with accuracy as the pyrophosphate if the precipitate by microcosmic salt in the nearly neutral solution containing ammonium chloride in the proportion of ten grams to one hundred cubic centimeters is allowed to stand several hours before filtering. In this way all cadmium separates out from the solution as a beautiful crystalline mass of cadmium ammonium phosphate of ideal constitution. The conditions must, however, be preserved with care; there must be no excess of ammonia, no free acid, and no excess of ammonium salt beyond the quantity indicated, while that amount is necessary.

ART. XXII.—*Separation of Iron from Chromium, Zirconium, and Beryllium, by the Action of Gaseous Hydrochloric Acid on the Oxides;* by FRANKE STUART HAVENS and ARTHUR FITCH WAY.

[Contributions from Kent Chemical Laboratory of Yale University—LXXXVII.]

IT has been shown in a former paper from this laboratory* that iron oxide may be completely volatilized as chloride by a strong current of hydrochloric acid gas acting at a temperature of 450–500°, and also that the addition of a little free chlorine to the gaseous hydrochloric acid renders this action complete at lower temperatures, 180–200°, without the danger of error arising from the liability of ferric chloride to dissociation, or from deficiency of oxidation in the oxide treated, or mechanical loss due to too rapid volatilization. It has also been shown that this reaction can be employed for the separation of iron and aluminum, taken as the oxides, and its application to the separation of iron from other metallic oxides has been suggested.

The oxides of chromium, zirconium, and beryllium, like aluminum oxide, are not acted upon by a current of dry hydrochloric acid gas at the temperatures before mentioned, and these oxides also can be entirely freed from iron by this reaction, as the experiments to be described will show. The procedure was the same in each case and analogous to that employed for the separation of iron from aluminum. A mixture of a weighed portion of one of these oxides with a weighed portion of ferric oxide, contained in a porcelain boat and placed within a roomy glass tube supported in a small combustion furnace, was submitted to the action of a dry current of hydrochloric acid gas and chlorine generated by dropping sulphuric acid upon a mixture of strong hydrochloric acid, common salt, and a small amount of manganese dioxide. The gas was admitted at one end of the combustion tube and passed out at the other through a water trap, while the required temperature, from 200°–300°, was maintained by regulating the various burners of the furnace. The time of action varies somewhat with the condition of the oxide to be volatilized, and the temperature, generally an hour's heating at 200°, proves sufficient for the complete removal of 0·1 gram of iron. At higher temperatures the action is more rapid; but the lighter oxide, the beryllium especially, is liable to mechanical loss through the too rapid volatilization of the iron, as experiment (17), where a temperature of 500° was used, will show. It is better, therefore, to use lower temperatures, raising the heat for a few minutes when the action is apparently complete to ensure the removal of the last traces of iron. Tests showed the residual oxides from which the ferric oxide had been removed in this manner to be entirely free from iron.

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* Gooch and Havens, this Journal,

Exp.	Fe_2O_3 taken. grams.	Cr_2O_3 taken. grams.	Cr_2O_3 found. grams.	Error. grams.
1	----	0·1008	0·1008	0·0000
2	0·1007	0·1006	0·1006	0·0000
3	0·1007	0·1000	0·1002	+0·0002
4	0·1010	0·1005	0·1003	—0·0002
5	0·1019	0·1006	0·1005	—0·0001
6	0·2007	0·1003	0·0999	—0·0004
		ZrO_2 taken. grams.	ZrO_2 found. grams.	
7	----	0·1516	0·1516	0·0000
8	0·1053	0·1010	0·1010	0·0000
9	0·1204	0·1519	0·1523	+0·0004
10	0·1236	0·1516	0·1517	+0·0001
11	0·2150	0·1517	0·1519	+0·0002
		BeO taken. grams.	BeO found. grams.	
12	----	0·1309	0·1311	+0·0002
13	----	0·1285	0·1285	0·0000
14	0·0997	0·0456	0·0457	+0·0001
15	0·1045	0·1099	0·1099	0·0000
16	0·1215	0·1080	0·1081	+0·0001
17	0·1510	0·1305	0·1290	—0·0015
18	0·2030	0·1081	0·1083	+0·0002

The separation of iron from chromium, zirconium, and beryllium by this method is obviously complete within very satisfactory limits of error.

ART. XXIII.—*An Albertite-like Asphalt in the Choctaw Nation, Indian Territory;** by JOSEPH A. TAFF.

History of its development.

IN the fall of 1897, while surveying the southern part of the McAlister Quadrangle in the Indian Territory, coal-like stringers interstratified with greenish shale were discovered in McGee Creek Valley. The stringers were one foot and less in thickness, and in places were intermingled with fragments of shale of the same nature as that in the wall rock. The shale upon both sides was of the same kind, was not carbonaceous, and was not of the nature of fire-clay as is usually found in contact with coal. The relation between the carbonaceous substance and the shale did not attract especial comment, since the rocks were nearly on edge and supposed to be in a faulted zone.

On working farther south in Impson Valley, T. 1 S., R. 15 E., an exposure of the same coal-like mineral was found cropping out in Ten Mile Creek in the same formation as on McGee Creek. The bed was partially concealed by water, but by good authority it was reported to be four feet thick. Still farther south on the west side of Impson valley, near the south side of T. 1 S., R, 15 E., the same mineral had been prospected and exploited on a small scale. A shaft twenty feet in depth had been sunk upon its outcrop where it was reported to be 25 feet thick and almost upon edge. The shaft was full of water at the time and the coal concealed.

The deposit was discovered by prospectors in 1890, exploited in 1892 and a little later abandoned because of the steep dip and friability of the product. Specimens were collected by the writer and submitted with a series of bituminous coals from the McAlister region for proximate analysis. These analyses were made by Dr. W. F. Hillebrand, and are placed here for comparison.

	Water.	Volatile Combustible Material.	Fixed Carbon.	Ash.	Sulphur.	Phosphorus.
Albertite.	·25	42·33	55·97	1·45	1·47	0·00
Coal. (Hartshorne)	1·63	38·27	55·15	4·84	1·51	0·014

The low percentages of water and ash in the albertite are the only features that would attract attention. On applying a flame to a fragment of the mineral it softens, disintegrates and ignites, burning for a short time after the removal of the flame. This, however, connected with the fusibility and friability of the mineral, indicates strongly that it is not a true coal.

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* Published by permission of the Director of the U. S. Geological Survey.

On returning to the field in 1898, a second inspection of the three localities of the mineral was made. It was found that Mr. Geo. D. Moulton had leased the lands including the prospects in Impson Valley. The mine near the south side of T. 1 S., R. 15 E., was being operated. Entries were made along the strike for 100 feet to both the foot and hanging walls. The mineral was found to form a vein, cutting folded green clay shale and striking nearly north and south and approximately parallel with the general trend of the rocks. The vein dips about 70 degrees east. The shale at both foot and hanging walls has been crushed so that its structure is destroyed and slickensided surfaces extensively developed. Two sets of joint planes bearing respectively northeast and northwest intersect the vein. The vein material, also, in some of the joints is striated, showing that there has been movement along such faces since the solidification of the mass.

The development of systems of joints in the vein intersecting approximately at 45 degrees to the face of the wall would indicate crushing pressure perpendicular to such faces while the mineral was in a solid or semi-solid state. The whole of the vein at the time when excavations had been made in it to a depth of about 30 feet showed indications of apparent crushing.

Mr. Moulton, the owner and operator of the mine, reports that at a depth of about 35 feet the vein for 12 feet inward from the foot wall has changed in structure. The specimens submitted by him, though small, show a compact mass with a smooth conchoidal fracture in contrast to the friable product with hackly surface found in the upper part of the vein and in the entire body of the vein to a depth of more than 30 feet.

Samples were collected from the face of the working 30 feet beneath the surface and submitted to Dr. Wm. C. Day for complete analysis. I quote the essential part of Dr. Day's report of the analysis. Duplicate tests were made in the determination of specific gravity, of solubility, and in the chemical analysis.

"*Report on the hydrocarbonaceous material supplied by Mr. Joseph A. Taff of the U. S. Geological Survey.*

The material is extremely brittle, pulverizing almost at a touch; it takes fire readily. It shows no sign of conchoidal fracture. Heated in a tube it does not melt but softens and gradually cokes progressively without becoming liquid at any one time.

Distillation of the asphalt from a retort showed that it does not entirely melt at any one time but softens and decomposes simultaneously like a coal. The distillate is dark red by transmitted light and shows a decided green fluorescence. For sake of comparison a quantity of soft coal used for making coal gas and obtained from a gas works was distilled. This gave a more tarry distillate but less in amount for equal weights of material. The odor of the distillate from the coal was markedly different from that from the asphalt; it lacked also the green fluorescence of the distillate from the asphalt. The coal was practically insoluble in carbon disulphide, while the asphalt was soluble to the extent of over 35 per cent.

The material, all things considered, resembles albertite more than any other of the asphalt substances, but it differs from it too in certain respects. For the sake of comparison the data contained in Dana's Mineralogy on albertite are placed here side by side with the corresponding data pertaining to the material supplied by Mr. Taff.

Albertite.	Mr. Taff's material.
Specific gravity 1·097.*	Specific gravity 1·175.
Color, jet black.	Color, jet black.
Softens a little in boiling water.	Does not soften in boiling water.
In the flame of a candle shows incipient fusion.	In flame of candle shows incipient fusion and takes fire, burning for a short time after removing from the flame.
Only a trace soluble in alcohol.	Only a trace soluble in alcohol.
4% soluble in ether.	5·34% soluble in ether.
30% soluble in turpentine.	Almost insoluble in turpentine.

Per cent. of carbon as found by Wetherill	86·04	Per cent. carbon	86·57
Per cent. hydrogen (Wetherill)	8·96	" hydrogen	7·26
" nitrogen (Wetherill)	2·93		
" nitrogen (Day)	1·84	" nitrogen	1·48
" sulphur (Wetherill)	trace		
" sulphur (Day)	0·17	" sulphur	1·38
" oxygen (Wetherill)	1·97	" oxygen	2·00
" ash (Wetherill)	0·10	" ash	1·31

Of the differences between albertite and the Taff asphalt the contrast in the solubility in turpentine is perhaps the most striking.

While the material submitted by Mr. Taff resembles a coal in the way it softens and decomposes under the influence of heat instead of entirely melting as asphalts generally do, the distillation products are markedly different from those of coals in abundance, in fluorescence, and in odor.

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* I find for Nova Scotia albertite sp. gr. 1·074 at 20·9° C.

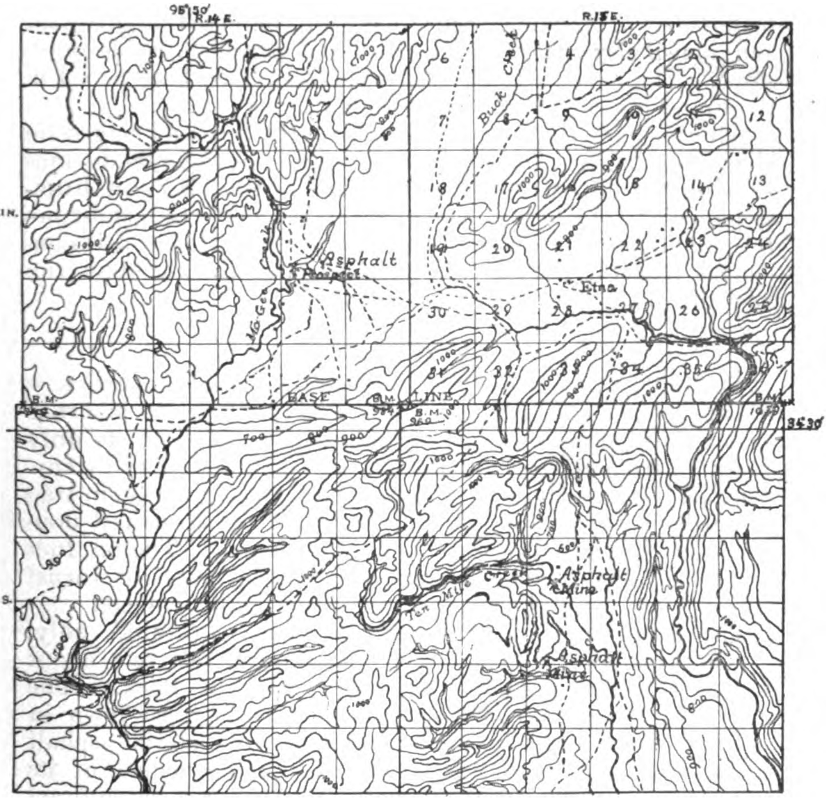
As the result of examining the analytical figures given in Dana's Mineralogy for a long list of coals, I can find none which even approximate those found for the material in question. The solubility in carbon disulphide classes the material with the asphalts, rather than with the coals. The analytical figures and the solubility show that the material resembles albertite from Nova Scotia more than any other of the asphalt-like bodies which have thus far been investigated."

Geology of Associated Rocks.

The map will show the general topographic character of the country as well as the located occurrences of albertite. It also gives the township land surveys which substitutes a scale for any location. The mapped district lies in both the McAlister and the Antlers Quadrangle. The parallel of latitude, 34° 30′, is the line between them, the McAlister being on the north. The contours mark elevations above the sea level and are at intervals of 100 feet.

The topography of the country is characteristic of the Ouachita mountain system in the Indian Territory to which it belongs. It is a system of rugged and generally parallel stony hills and small mountains which rise to elevations of from a few hundred to a thousand and even more feet above nearly level plain-like valleys which are often several miles wide and many miles long. These plain-like valleys are governed by and limited to the outcrop of shales and other associated friable rocks. By observing the map a wide valley may be noted extending from McGee Creek in the north part of T. 1 S., R. 14 E. northwestward to Buck Creek, where it is divided by the Jack Fork Mountains. There is another such valley known locally as Impson Valley in the center T. 1 S., R. 15 E., in which the asphalt mines are located. The mountains, hills and all elevated lands are rugged and are held up by many beds of hard sandstone whose edges are exposed. The streams in the plains have little or no valleys of their own. Their channels, also, are little more than ditches cut in the soil and soft rock. The streams which flow in or across the hilly country are confined to narrow and often deep gorges or valleys.

The structure of the rocks, especially that of the shales, is hard to interpret. Besides having been folded and faulted to an extent difficult of appreciation, the beds are almost entirely concealed by soil and rock debris. It has been clearly determined, however, that the beds have been folded along lines northeast and southwest, then overturned towards the northwest and, in many places, faulted. Especially where shales are involved the crushing and faulting has been very extensive. Three lines of faulting bearing northeast and southwest and having displacements of many hundred feet, extend along the southeast sides of the group of hills through the center of T. 1 N., R. 14 E., of the Jack Fork Hills in the center of T. 1 N., R. 15 E. and of the hill in section 3, T. 1 N., R. 15 E. respectively. The latter two lines of faulting extend from the ends of the hills southwestward into the plain toward the albertite exposures.



Map to show location of asphalt mines in Choctaw Nation.

Another zone of faulting extends from the plain nearly two miles east of Etna bearing southwestward, crossing the center of the south side of T. 1 N., R. 15 E. thence nearly due south along the west side of Impson Valley. The albertite mines of this valley are located along this fractured zone. The north end of this valley, in Section 10, T. 1 S., R. 15 E. is anticlinal and the rocks along the east side of the valley dip normally toward the east. On the west side, however, the older shales which contain the albertite are thrust upward against the younger sandstones of the hills.

The geology, were it not for the complications of structure, would be simple, For all purposes necessary here, however, the problem of the geology may be briefly stated. The shales which lie in the plains and wide valleys noted above, and which contain the albertite, are the oldest known in this district. Their thickness is difficult to determine, though it is estimated to be several thousand feet. They are composed of greenish and bluish clay shales, sandy shale and greenish friable sandstone. Thin beds of black siliceous slate have been noted in the upper part of this body of shale.

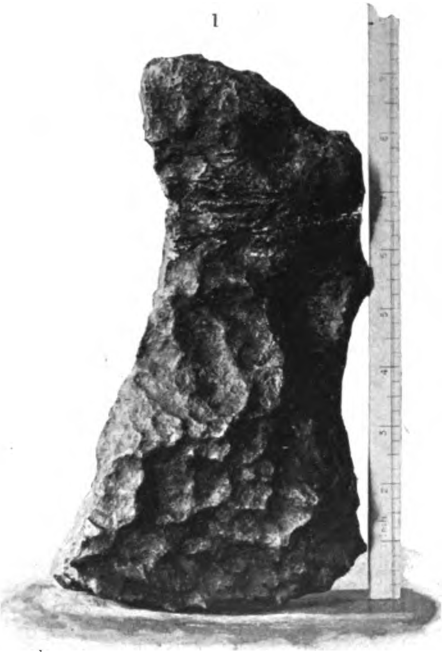
All the thick sandstones which form the hills and ridges lie above the shales. The aggregate thickness of these sandstones is estimated also to be several thousand feet. Beds of limestone which have been found to occur just above the sandstone formation contain fossils of Ordovician age. Hence it is concluded that the sandstones and the shales which contain the albertite are of Ordovician age or older.

Conclusions.

The mineral, in both its physical and chemical properties, is shown to be an asphalt and more closely related to albertite than to any other known asphalt substance. Indeed its only variation from albertite of any moment is its solubility in turpentine. The friability and fracture of the sample submitted for analysis is, without much doubt, due to its structural condition produced by pressure after solidification. The product occurs as veins or dikes filling fissures along zones of thrust faulting. It occurs in shales of, at present, unknown age.

The quantity of this asphalt can be conjectured only. As far as known it occurs in thin stringers, in a vein about 4 feet thick, and in a vein about 25 feet thick. The surface of the shale containing the product is worn down in valleys and concealed by soil or overwash so that the asphalt is known only so far as prospected. From the manner of its occurrence in fissures produced by fracture, where it has suffered probably great pressure, the vein is supposed to vary in thickness and in longitudinal extent and may descend to any reasonable depth.

1



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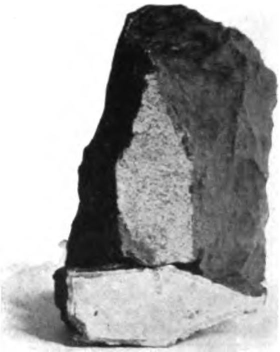

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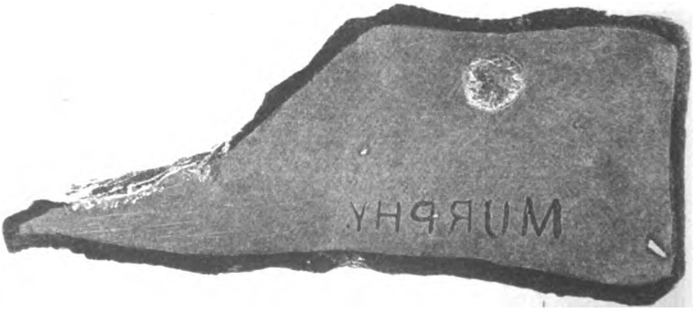

Art. XXIV.—*Notice of a new Meteorite from Murphy, Cherokee Co., N. C.;* by Henry L. Ward, Rochester, N. Y. With Plate IV.

In May of the present year we received word from Mr. W. B. Lenoir that he had what he supposed to be a meteorite that he desired to sell. Upon request he forwarded it to us; and a superficial glance at the well-pitted surface was sufficient to determine that it was a siderite.

Under date of May 25th, Mr. Lenoir writes: "It was ploughed up or washed out in a field in Cherokee Co., N. C., five miles from Murphy. From the location [where] found I think it must have been washed out by some of the immense rains which fell in that section last winter. . . . The small piece enclosed with the larger one was broken off when I purchased it. . . . The stone [iron] I understand was found about six weeks ago." Later he writes: "In answer to yours of June 10, asking how the meteorite was broken, will say that I did not break the meteorite. The man who first showed me the piece said that they attempted to cut it with a cold chisel and did not succeed. By some means (I think he said) they cut around it and then either with a blow or by prizing broke it off. . . . He said he had a 'hell of a time' breaking it."

As was to be expected, this meteorite adds another to the great majority of siderites the date of whose fall is unknown.

Fig. 1, Plate IV, shows the iron with the broken piece set in place so as to give the original form. Its height is 23·5^{cm}. A rectangle drawn about the base upon which it stands measures 13·4×11·5^{cm}. The weight of the iron was 7753 grams (17 lbs. 1½ oz.), of which the broken end weighed 808 grams. Another photograph of the entire iron was taken to show the remarkably sharp angle formed by the left hand edge and the side opposite to that shown in fig. 1; but a defect in the plate rendered this photograph unusable. Fig. 2, showing end views of both pieces from the broken surface, gives something of this angularity, which was rather more marked lower down. In some of the larger sections cut across the iron this angle is rather more acute than a right angle, as this side is somewhat concave, and the edge is very sharp. These two surfaces are less deeply pitted than the one shown in the figure; and convey the impression that the meteorite in hand is but a fragment of a larger one that broke not far above the earth. Had it traveled far since dividing we would expect the angles to be rounded. An examination of the crust fails to give any evidence for or against this theory. Flow lines, if they ever existed, have been removed by weathering and the oxidized crust appears equally thin on all sides. The fact that the edges of the mass are approximately parallel to the lines of crystallization is only in accordance with what has been shown to be common to siderites in general.

The square fracture is an interesting feature that I believe to be quite unusual in iron meteorites. Its surface is nearly a parallelogram $4{\cdot}8\times3{\cdot}3^{cm}$, with one of the shorter sides surmounted by a triangle $3{\cdot}5^{cm}$ in height; giving a surface of approximately $21{\cdot}5^{sq\ cm}$. One side shows that it has been cut by a cold chisel to a depth of about 2^{mm}. The rest of the face is a clean straight break with a hackly surface. This is shown on the larger mass in fig. 2.

The etched surface presents two main series of lines enclosing rhombs having the angles 161·2 and 18·8; other lines crossing these produce all the figures compatible with the twinning about a cube with the exception of a single line, which probably exists but which I have been unable to find.

Under the microscope each higher power up to about one hundred diameters reveals lines not seen with lower powers. That the series of lines giving the angles above mentioned are the primary ones, is indicated by the fact that the lines of fracture on the broken face have followed these. On a section cut at right angles to these, the lines apparent to the eye give decidedly larger figures; but under the microscope this distinction disappears.

The Neumann lines were visible in the photograph of the etched end shown in fig. 2; but are entirely lost by the screen used in making the half tone; consequently we introduce a print directly from an etched section of the iron, fig. 3, which under a hand lense should show the lines fairly well.

Troilites appear in all the sections; but are in most cases of very small size. The largest one that appears measures 9×13^{cm} in diameter. It is interesting to note that the Neumann lines are materially flexed immediately about some of the troilites: indicating that they existed in a plastic condition during the growth of the troilites.

Daubreelite, in unusually large masses, occurs in two of the slices; both as veins crossing the troilites and as solid masses at the sides. The largest mass measures, on its two nearly rectangular faces, 5·5 and 5^{mm}; the other sides being formed by a segment of the nearly circular border of the troilite within which it has formed.

An analysis of the iron has not yet been made.

Unfortunately the more euphonious title "Cherokee County" has already been applied to the Losttown, Cherokee Co., Ga., siderite, and we are forced to adopt the less pleasing one of the town near which it was found, *Murphy*, as the name for this meteorite.

ART. XXV.—*On the Separation of Alumina from Molten Magmas, and the formation of Corundum;* by J. H. PRATT.

SOME interesting problems have arisen, in recent years, regarding the differentiation of igneous magmas upon cooling. It has been the author's privilege during the last three years to study in the field various occurrences of corundum, spinel and chromite in peridotite rocks, and in some recent papers* the igneous origin and the chemical composition of these minerals have been discussed by him. It is the intention in this paper to give those field observations that have a theoretical bearing upon the separation of these minerals from a molten magma and more especially of the alumina.

The results of the elaborate studies that have been made by Vogt,† Morozewicz,‡ Lagorio§ and others upon the artificial formation of minerals in molten magmas, have been verified by observations upon the occurrence of the same minerals in nature that have also separated out from molten magmas.

The separation of alumina is well illustrated in nature in the occurrence of corundum, spinel and chromite in the rocks of the peridotite group. Of these rocks, the most common one containing these three minerals is dunite, consisting almost entirely of chrysolite or its alteration product, serpentine. In the analyses of the dunite rocks, they show either a trace or very small percentage of alumina or chromic oxide or even none; and in the analyses of other peridotites than dunite, the same usually holds true for amounts beyond those required in the composition of the normal minerals that compose these rocks.

The peridotite localities that have been examined by the author are all located in the western part of North Carolina, and at these various localities the following phenomena have been observed:

1. Peridotite rocks containing small particles and grains of chromite but no corundum or spinel.
2. Peridotite rocks containing deposits of chromite (which upon analysis showed a variable per cent of alumina and magnesia), but no corundum or spinel.
3. Peridotite rocks containing chromite, corundum and spinel.

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* This Journal, vol. vi, July, 1898, p. 49; ibid. vol. vii, April, 1899, p. 281, and Trans. Am. Inst. Mining Eng., vol. xxix, 1899.

† Zeitschr. für Prakt. Geol., Nos. 1, 4 and 7. 1893.

‡ Zeitschr. für Kryst., vol. xxiv, p. 281, 1895, and Tschermak's Min. u. Petrog. Mittheilungen, Bd. xviii. H. 1-2-3, pp. 1-90 and 105-240, 1898.

§ Zeitschr. für Kryst., vol. xxiv, p. 285, 1895.

4. Peridotite rocks containing chromite and corundum, but no spinel.

5. Peridotite rocks containing corundum and feldspar.

1 *and* 2. In the analyses of the chromites that have come under the author's notice, all but two show the presence of alumina and magnesia in varying amounts. In some of them the percentage of alumina and magnesia is very large and where in the ordinary chromite the formula may be represented by 9 ($FeO.Cr_2O_3$), ($MgO.Cr_2O_3$), 2 ($MgO.Al_2O_3$); at one locality near Webster, Jackson County, a chromite (*mitchellite*), was found which had the formula ($FeO.Cr_2O_3$), ($MgO.Cr_2O_3$), 2 ($MgO.Al_2O_3$). Thus when there is considerable chromite found in these rocks, there is usually no, or at most but a trace of corundum present, and from what has been said above regarding the analyses of chromite, it would seem to be the case that when there is but little alumina and only a small excess of magnesia in peridotite magmas, containing considerable chromic oxide, that they unite to form the spinel molecule which instead of separating out independently as the mineral spinel, enters into combination with the $FeO.Cr_2O_3$ molecule in the mineral chromite.

3. At a few of the peridotite localities both corundum and spinel have been found, as at the Corundum Hill Mine, where a fine-grained, almost black spinel occurs through which is scattered particles and masses of corundum; and at the Carter Mine near Democrat, where there is a great abundance of corundum and a green black spinel. In peridotite magmas of this type, it would seem that there has been an excess of magnesia present which has united with a portion of the alumina present to form the molecule $MgO.Al_2O_3$, which separated out as spinel. The remaining portion of the alumina formed corundum.

Undoubtedly there is a strong affinity between magnesia and alumina which tends to form the spinel molecule; but in these peridotite magmas, it is only the excess of magnesia over that required for the normal magnesian silicates that has united with the alumina. Except alteration products there are no alumina-magnesia silicates found in these rocks, showing that in magmas of this type there is no tendency for the alumina to unite with the magnesia in forming double silicates.

4. At most of the peridotite localities there has been no spinel at all observed, but there is often a considerable quantity of corundum found. The chromite at all these localities shows the presence of a certain percentage of alumina and magnesia. Thus the small excess of magnesia unites with a definite amount of the alumina, but instead of separating out as spinel, it separates out in the chromite molecule as previ-

ously mentioned. The greater part of the alumina separates out as corundum.

5. In a number of these peridotite formations feldspar has been found which is undoubtedly one of the original minerals of the rock and not a secondary product.

At the Cullakeenee Mine, Buck Creek, Clay County, there is, at one of the contact corundum veins, a large amount of feldspar and hornblende which have separated out with the corundum: again at the Bad Creek Mine, Sapphire, Jackson County, the corundum is found associated with feldspar and biotite mica. In both places they are lime-soda feldspars, and this occurrence of feldspar and corundum in a peridotite rock indicates that the molten magma contained some of the alkali and alkali earth oxides, as Na_2O, K_2O and CaO, and that a portion of the alumina united in the formation of the feldspar molecule and that the rest of it separated out as corundum. In a magma of this type, there is present a large amount of magnesia which forms the magnesian silicates but apparently has no tendency to unite with the alumina to form the spinel molecule; but on the other hand the small amount of the alkalies and alkali-earth oxides do unite with a definite amount of the alumina to form the feldspar molecule. This again would seem to indicate, that in the presence of a certain amount of the alkali and alkali-earth oxides and silica that if there is enough silica present to unite with these oxides and the magnesia, there is no tendency for the magnesia to unite with the alumina to form any type of magnesia-alumina minerals.

Morozewicz* has recently described the formation of corundum from a number of magmas that were supersaturated with alumina. The supersaturated alumina-silicate magmas had the general composition $MeO . mAl_2O_3 . nSiO_2$($Me = K_2, Na_2$, Ca, and $n = 2-13$). In these magmas, on cooling, all the excess of alumina (over $m = 1$) separates out in the form of corundum crystals, this taking place when magnesia and iron were not present.

In these experiments, the silicates that were used to form the magmas were for the most part those of calcium, sodium and potassium. When alumina was present in them in excess of $m = 1$, it would separate out in the form of corundum; but when the magma was not saturated with alumina or m was equal to 1 or less, all the alumina was used up in the formation of double silicates. When magnesia was present, the excess of alumina united with the magnesia to form the mineral spinel, and if not enough magnesia was present to unite with all of the alumina, some corundum was formed. When there was an excess of silica, or *n* is greater than 6, the excess of alumina unites with the silica to form the mineral sillimanite and the over excess of alumina would separate out as corundum. When, however, magnesia and iron are present with the excess of silica and alumina, cordierite and spinel are the minerals formed.

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* Tschermak's Min. u. Petrogr. Mittheilungen, xviii, pp. 1–90 and 105–240, 1898.

From these experiments it would seem that where a magma is composed of silicates of the alkali and alkali-earth metals, sodium, potassium and calcium, that the alumina dissolved in this magma will to a certain point unite to form double silicates of alumina with these other bases; but when the ratio of alumina to these bases is greater than 1, the excess of alumina will separate out as corundum except when influenced as just described. Magnesia, it would seem, does not have as strong an affinity for the formation of silicates, and when present in the magmas, influences the separation of the alumina as a double salt of magnesia and alumina in the formation of the mineral spinel, or with an excess of both alumina and silica in the formation of the mineral cordierite.

In some earlier experiments, Morozewicz* has shown that alumina will readily dissolve in a molten magma having a composition approximately that of the basic magnesian rocks; and that upon cooling the alumina separates out as corundum and spinel.

There seems to be but little tendency for the alumina to unite with the magnesia to form the double silicates or with the magnesia alone to form the mineral spinel, $MgO.Al_2O_3$, except when there is an excess of MgO, when some spinel is formed, but the greater portion of the alumina separates as corundum. This would seem to show that the affinity of magnesia for silica in the formation of a silicate molecule is stronger than for alumina to form the aluminate molecule.

Summary.—From what has been observed in nature and from the experiments that have been made in the laboratory, it seems that the separation of alumina as corundum from molten magmas is dependent upon the composition of the chemical compounds that are the basis of the magma, upon the oxides that are dissolved with the alumina in the magma and upon the amount of alumina itself.

1. When the magma is a calcium-sodium-potassium silicate, no alumina held in solution by such a magma will separate out as corundum except when the ratio of the alumina to the other bases is more than 1 : 1 and the ratio of the silica is less than 6.

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* Zeitschr. für Kryst., vol. xxiv, p. 281, 1895.

2. If magnesia and iron are present in the above magma, corundum will not form unless there is more than enough alumina to unite with the magnesia and iron.

3. When the magma is composed of a magnesium silicate without excess of magnesia, *all* the alumina held by such a magma will separate out as corundum.

4. Where there is an excess of magnesia in the magma just described, this will unite with a portion of the alumina to form spinel and the rest of the alumina will separate out as corundum.

5. Where there is chromic oxide present in a magma composed essentially of a magnesium silicate (as the peridotite rocks) and only a very little alumina and magnesia are present, these, uniting, separate out with chromic oxide to form the mineral chromite and no corundum or spinel are formed.

6. When peridotite magmas contain, besides the alumina, oxides of the alkalies and alkali-earths, as soda, potash and lime, a portion of the alumina is used in uniting with these oxides and silica to form feldspar.

7. There is a strong tendency for the alumina to unite with the alkali and alkali-earth oxides to form double silicates like feldspars, whether such silicates form the chief minerals of the resulting rock or are present only in relatively small amount. There is, however, but little tendency for the alumina to unite with magnesia to form double silicates when the magma is a magnesium silicate.

North Carolina Geological Survey, June, 1899.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY AND MINERALOGY.

1. *Canada; Summary Report of the Geological Survey Department for the year* 1898.—Among the items of general interest in the report are the following:

"The aggregate value of the production of minerals in Canada during the year 1897, as finally corrected and published, is $28,661,430, being an increase of about 27 per cent over that of the previous year. This is largely accounted for by the great development of gold mining, particularly in the Yukon district, the value of the gold produced being more than double that for 1896."

The Director examined the North Saskatchewan gold district, where much interest is taken in the use of dredging machinery to gather the river gravels. He reports regarding the occurrence of the gold in the "Saskatchewan gravels," that

"Gold in fine scales and particles, generally so minute as to require the employment of mercury in collecting it, is now known to occur on almost all the rivers running eastward from the Rocky Mountains, to the north of the International boundary, wherever these have been prospected. To the south of the Peace River, this gold, in any workable quantity, seems invariably to characterize a portion of the length of each of the rivers, giving out to the westward before the base of the Rocky Mountains is reached, and to the eastward along a less well defined line, but one probably due, in this case, to the local substitution of sand and clay banks and beds for the gravel bars of the upper and more rapid parts of the streams. The Peace River and the Liard, rising to the west of the Rocky Mountains proper, among rocks known to be auriferous, contain more or less gold throughout their lengths, or to points in their lower courses where the changed conditions of flow, above alluded to, render the collection of any minutely divided gold which they may still carry practically impossible. In other words, in these two rivers, and possibly also in some still farther to the north, a considerable part at least of the contained gold comes directly from their upper tributaries; while in the case of the Athabasca, the North Saskatchewan and other rivers farther to the south, the evidence at first sight appears to be entirely against the possible derivation of gold from the mountains to the westward."

"The result of recent observations appears, therefore, to indicate that the gold found in the Saskatchewan and other rivers of the Northwest has come in part from several sources, but has been derived chiefly from the crystalline rock of the Laurentian axis or plateau to the eastward or north-eastward, from which it has been transported with the fragments of these rocks that now form so conspicuous a part of the 'drift' of the Great Plains.

The recognition in late years of the Huronian as a distinctly gold-bearing formation, in itself goes far to establish the correctness of the hypothesis originally advanced on this subject, as rocks of this formation occupy considerable areas of the Laurentian plateau."

In these gravel deposits, six miles above Edmonton, bones of *Elephas primigenius* or *Americanus*, and of *Ovibos moschatus* have been discovered.

The overthrust faults in the Cretaceous coal-bearing district of Crow Nest Pass, on the eastern side of the Rocky Mountains, lead to the expectation of finding coal beds of Cretaceous age below Paleozoic limestone.

This peculiarity in the structure is adduced as an explanation of the petroleum occurring in rocks of which the surface is of probable Lower Cambrian age—between Crow Nest and South Kootenay passes in the southern part of the Rocky Mountains.

The borings for petroleum at Athabasca Landing have been continued, but without practical success. Mr. Fraser explains the hindrance to attempts to reach the sources of the petroleum in his report as follows:

"The bore at Pelican River had been stopped at 820 feet owing to the striking of an immense flow of gas, which made it impossible to work while it continued to flow with such force. It was thought that by the spring of 1898 it would have exhausted itself sufficiently to permit further boring, and to this end the casing, 4⅝ inches in diameter, was left quite free and open to permit the escape of the gas. It was estimated that before a depth of 1000 feet was encountered the Devonian limestone would be pierced.

"Upon investigation in the early part of the present season, the flow of gas seemed to have very materially decreased; but upon operations being resumed, the seeming decrease was found to be in a great measure due to the closing up of the outlet at the bottom part of the casing by an asphalt-like mixture, composed of maltha, or petroleum tar, and sand. In fact, when boring operations were resumed on June 17th, the difficulty was found to be intensified by the accumulation of this asphalt-like maltha in the bottom of the bore.

"The rapid expansion of the gas produced a very low temperature, and this chilled and solidified the tar, or maltha, until it became as adhesive as wax. As the tools cut it loose the gas would carry it up through the bore, until from bottom to top it was almost one mass of sand and tar. The only way it could be extracted from the sand-pump was by heating the latter over a fire; even then very little could be got out at one time, it being so thick that it was almost impossible to force it up into the pump. I used different sorts of tools to cut it off the walls and clean it out, but the longer we worked at the bore the greater the quantity of tar accumulating on the sides of the casing and tools."

On the Pembina River in northern Alberta, Mr. McEvoy reports:

"Several outcrops of coal occur on the banks of the river, principally above the crossing. The coal has been on fire here years ago, and the overlying beds of clay and shale have fallen in, giving a very disturbed appearance to the locality. The white clay is partly burned to a pale red terra cotta. Half a mile above the crossing, on the east side, a seam of coal 17 feet 10 inches thick is exposed, of which the upper four feet is impure. On the opposite side there is a seam 13 feet thick, having four small partings of clay and carbonaceous shale, amounting in all to nine inches."

Dr. Adams in his study of the Grenville series in Monmouth reports important evidence of their sedimentary origin. He says:

"The study of the Grenville series in Monmouth showed beyond a doubt, that this series is a sedimentary one. It includes a great development of bedded white quartzites, evidently altered sandstones. The associated limestones also, that occur in heavy bands, and, as everywhere else in the Grenville series are in the form of white crystalline marbles, were in a few places along the line of the Irondale, Bancroft and Ottawa Railway, seen to hold little dark strings suggestive of remnants of the original limestone in a less altered condition. On this account, a careful search was made, which resulted in the discovery of two localities in which the limestone was almost unaltered, being very fine in grain and blue in color, and bearing a strong resemblance to the limestones of more recent formations. In such case the blue limestone is interstratified with the ordinary white coarse-grained marble of the Grenville series and passes into it, there being evidently portions of the limestones which have escaped metamorphism. These occurrences serve to dispose of any lingering doubts concerning the sedimentary origin of the limestone in question."

Silurian fossils were discovered about six miles from Canterbury station of the St. Andrews and Woodstock branch of the Canadian Pacific Railway, in a belt of rocks lying northwest of the granite area in western York. The rocks in question have hitherto been classified as Cambro-Silurian. They are partially altered gray slates. The fossils, according to Dr. Ami, indicate uppermost Silurian.

Along the shore of Grand Manitoulin Island, Lake Huron, a coralline limestone containing Lower Niagara fossils is reported by Dr. Ami.

Foot-prints of *Hylopus* and *Sauropus*, and other evidences of Carboniferous, have been reported from the fossiliferous strata along the north shore of the Basin of Minas.

"The bone-beds of McAra Brook, holding crustacean and fish remains, were again examined and additional examples were obtained of a *Pteraspis*, which appears to be new (the genus having been identified by Dr. A. S. Woodward), and fragments of cephalaspidian and acanthodian species, besides indications of

Pterygotus. The occurrence of *Pteraspis* and *Pterygotus* indicate that the beds at McAra Brook, above and below the post-road, are referable to the summit of the Silurian system or the lowermost portion of the Devonian."

Mr. Lambe reports the following Cretaceous fossils from Red Deer River district of Alberta, viz.:

"Considering first the fossils from the Belly River formation, the following provisional enumeration may be made of them:—

1. Chelonia:
   Fragments of the dorsal and ventral shield of *Plastomenus coalescens*, Cope.
2. Crocodilia:
   Parts of the rami of mandibles of a species of *Bottosaurus*, Agassiz.
3. Dinosauria:
   a. Numerous maxillæ and rami of mandibles and some of the principal bones of *Trachodon mirabilis*, Leidy.
   b. A maxilla with teeth, a separate tooth and a right ramus of a species of *Triceratops*, Marsh.
   c. Separate teeth and terminal phalanges of *Lœlaps incrassatus*, Cope.
   d. The upper part of the cranium of a species of *Nodosaurus*, Marsh." w.

2. *The Hereford Earthquake of December 17, 1896;* by Charles Davison, Sc.D., F.G.S., 303 pp. 8vo. Birmingham, 1899 (Cornish Brothers).—The careful investigation of the phenomena connected with an important earthquake is a laborious undertaking, but one which is of great value in its bearing upon our knowledge of earthquakes in general. In the case of the Hereford earthquake of Dec. 17, 1896, discussed in the present volume, Dr. Davison has shown unwearied energy in bringing the data together and much judgment and skill in drawing conclusions from them.

Of the several regions in Great Britain in which notable earthquakes have taken place, that of the occurrence here described, in the southeast of Herefordshire, is especially favorably situated for observation both geographically and as regards distribution of population. Here occurred also the earthquake of October 6, 1863, investigated by Mr. E. J. Lowe; while another, less violent, occurred in October 30, 1868. In 1896, however, the shocks were more numerous and severe, resulting in a very considerable amount of damage to buildings in the region of greatest intensity about Hereford. The effect was distinctly felt even at extreme points in the north and south of England and in Ireland.

The record of observations, contained in Part I (pp. 10–201) of the present volume, includes some 2902 separate accounts from 1943 places. The discussion of these data has made it possible to locate with accuracy the epicentral region with the isoseismal lines; also the isacoustic lines, or lines of equal sound intensity; the direction of the shocks at various points with the coseismal lines. From the last the mean surface-velocity deduced between the first and third coseismals is 2955 feet per second.

In regard to the origin of the earthquake the conclusion is reached that it was due to a slip along a fault many miles in length having a general northwest and southeast direction and passing very near to Hereford. Further that there were two foci, one to the northwest near Hereford some eight miles in length, and a second, southeast and near Ross, about six miles in length. Between these there was an undisturbed portion of the fault about two miles in length. The fault-slip at the Hereford focus took place a few seconds before that at the Ross focus, hence the distinctly noted double series of vibrations. The position of the fault-line is located within the area of the Old Red Sandstone, but its exact geological relations have not been established, though it is plausibly connected with a well-recognized anticlinal in the neighborhood, bounded on three sides by faults, one of which has nearly the direction of the fault-line above mentioned.

3. *First Appendix to the Sixth Edition of Dana's System of Mineralogy*, by EDWARD S. DANA; pp. x and 75. New York, 1899 (John Wiley & Sons).—The sixth edition of Dana's System of Mineralogy was issued in the early part of 1892. In the seven years that have passed, the additions to mineralogical literature have been numerous and important; a summary of these is given in the Appendix now published, which thus completes the System to 1899. The prefatory note states as follows: "This Appendix contains, first of all, full descriptions of the species announced as new since the publication of the System. There are no fewer than one hundred and seventy names here included, and their place in the general scheme of classification adopted in the System is shown in the classified list given in the Introduction. In addition to the description of new minerals this Appendix is intended to contain also references to all important papers on mineral species published during the period named; with each reference is given a concise statement of its character, and so far as possible a summary of its contents. Since, however, the additions to mineralogical literature have been very numerous, it has been necessary, in order to keep this work within reasonable compass, to adhere rigidly to a system of extreme brevity of expression and conciseness of arrangement. All minerals named are, for convenience, placed in alphabetical order. . . . The Bibliography includes the full titles of prominent volumes published since 1891."

4. *Minerals of Mexico.*—Boletín del Instituto Geológico de Mexico, num. II, pp. 157, 4to. Mexico, 1898.—The latest number of the Bulletin published by the Geological Institute of Mexico contains a full and valuable catalogue of the mineral species found in the country, prepared by Prof. JOSÉ G. AGUILERA. In it the minerals are arranged according to the classification in Dana's System, the individual localities being given fully in connection with each species.

5. *Clays and Clay Industries of Pennsylvania.* (1) *Clays of Western Pennsylvania in Part:* by THOMAS C. HOPKINS.—This volume is issued as an appendix to the Annual Report of the Pennsylvania State College, for 1897. In it Professor Hopkins has given an interesting and instructive account of the various clays obtained in Western Pennsylvania, and further a description of the industries connected with their use. Numerous excellent illustrations accompany both parts of the subject.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Eruption of Mauna Loa.*—Honolulu papers of July 8 to 10 contain accounts of the beginning of an eruption of the volcano of Mauna Loa, on Hawaii. Early in the morning of July 4th, one observer says, "an immense column of smoke and steam was seen rising from the crater of Mokuaweoweo. It was pierced through with the light from the fires beneath, until it glowed and shone like a column of fiery light, resplendent beyond description, and reflecting its burning glow over the whole heavens. The column seemed to be at least five miles in diameter, and rose to a tremendous height. On Tuesday, the column of fire had disappeared. In place of it was the equally impressive glow of the lava as it broke from the lower side of the crater several thousand feet lower down than the column of light had been, and was thrown upward to a wonderful height by the forces which were in action. On either side of the stream, whose surface of fiery red could be seen like a line of glowing molten metal, were two cones which had formed since the eruption began. It was from these that the lava was being ejected. It was thrown up in fiery cascades high in the air. These cascades, in falling, built up the cones, and the molten lava running off from these formed the stream flowing off toward Hilo. It would be hard to say how high these cones were, perhaps somewhere between 500 and 1000 feet high, and half a mile in diameter, and five miles apart." A later account mentions three lava streams, one in the direction of Hilo, another off through Kau to the southeast, and a third toward the crater of Kilauea.

Attention may be called in this connection to a paper by Mr. C. J. Lyons of Honolulu on "Sun Spots and Hawaiian Volcanoes" published in the April number of the *Monthly Weather Review*. The author gives a table of the years of minimum sun spots for the past century, with the dates of prominent volcanic eruptions of Kilauea or Mauna Loa, showing a striking correspondence between the times of the two phenomena. As pointed out by the editor of the *Review*, however, a more thorough investigation is needed to prove that the coincidence noted is due to a real causal connection.

The table referred to is as follows:

Years of minimum sun spots.	Years of most important lava flows or eruptions.
(?)	1790 (Kilauea Keoua eruption).
1799	1801 Hualalai.
1810	(?)
1823	1823 Mauna Loa.
1833	1832 Mauna Loa and Kilauea.
1843	1840 Kilauea. 1843 Mauna Loa.
1856	1852 1855 1859 } Mean 1856, Mauna Loa.
1867	1868 Mauna Loa.
1878	1880-81 Mauna Loa.
1889	1887 Mauna Loa, south slope.
1900 (Probable)	----

2. *British Association.*—The coming meeting of the British Association for the Advancement of Science is to be held at Dover during the week beginning Sept. 13th. The occasion is expected to be a notable one and of international character, since the French Association meets at the same time at Boulogne and visits are planned for the two scientific bodies, on September 16 to Dover and on Sept. 21 to Boulogne.

3. *American Association.*—The summer meeting of the American Association for the Advancement of Science was held at Columbus, Ohio, from August 21–26. An account of the meeting must be postponed to the following number.

4. *Sprachregeln für die Bildung und Betonung Zoologischer und Botanischer Namen;* von PAUL KRETSCHMER. 8vo, 32 pp. Berlin: 1899 (R. Friedländer & Sohn).—This pamphlet gives very full and carefully prepared grammatical rules for the formation and accentuation of zoological and botanical names and should be consulted by every naturalist interested in systematic nomenclature. S. I. S.

5. *Anleitung zur Darstellung Chemischer Präparate*, von Prof. Dr. H. ERDMANN. 2 Auflage; pp. 92. Frankfurt, 1899 (H. Bechold).—The first edition of Prof. Erdmann's little book on Inorganic Preparations appeared nine years ago, and has been very favorably received. This new edition, containing a few additional preparations, with numerous corrections and improvements, will, therefore, be welcomed by those who are interested in teaching experimental chemistry. H. L. W.

OBITUARY.

Sir WILLIAM HENRY FLOWER, K.C.B., F.R.S., the distinguished Zoologist, late Director of the Natural History Department of the British Museum, died on July 1 in his sixty-eighth year. His contributions to zoology, anatomy and anthropology were numerous and important, and in his capacity of museum curator he performed a work of great and lasting value, the influence of which has been widely felt in other institutions at home and abroad.

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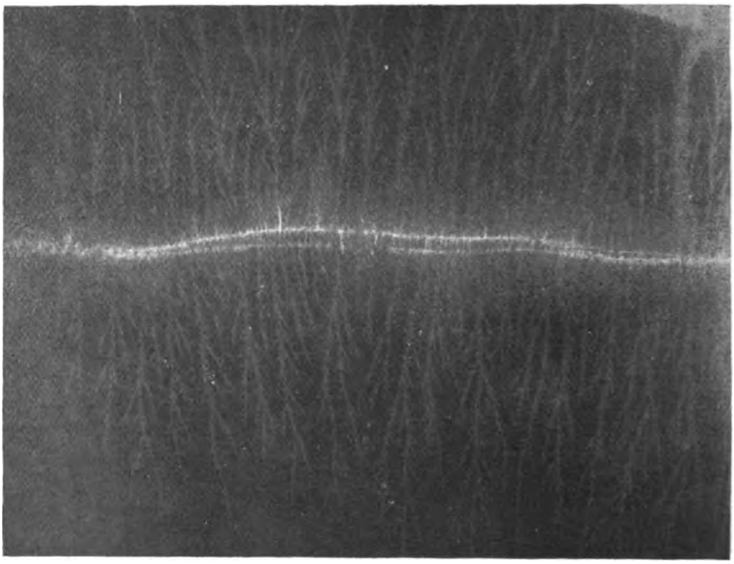

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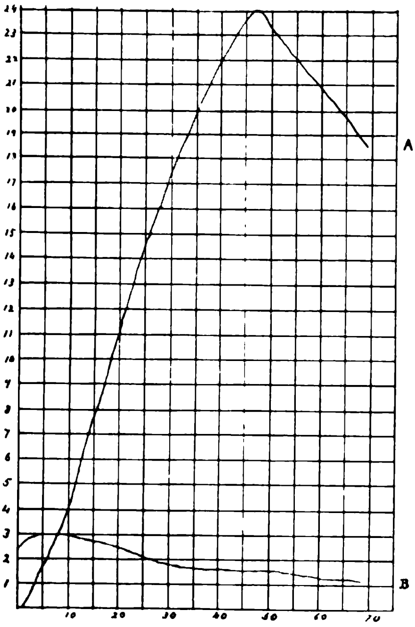
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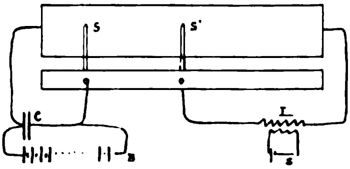
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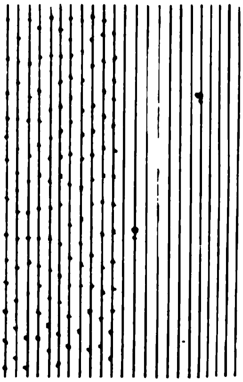

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVI.—*Explosive effect of Electrical Discharges*; by JOHN TROWBRIDGE, T. C. MCKAY and J. C. HOWE. With Plate V.

SINCE the time of Franklin the subject of the explosive effect of electrical discharges has been studied by numerous investigators, and an extended bibliography of their work is contained in Wiedemann's "Galvanismus und Electromagnetismus."

The resources of the Jefferson Physical Laboratory permitting the study of this phenomenon over greater range than has hitherto been possible, we have undertaken the work in the hope of further elucidating the subject. The laboratory possesses two high tension transformers or Planté rheostatic machines—one giving discharges of 125 centimeters in length, and one yielding sparks 180 to 200 centimeters in length. These transformers are connected to a battery of ten thousand cells, and can yield voltages from twenty thousand to three million. Various methods of measurement were tried. On account of the great tension all galvanometric and electrometric means had to be abandoned; and what is known as the electric thermometer was finally adopted. This consists, as is well known, of a hermetically closed glass tube, provided with a manometer gauge. The electrical discharge passes through the tube by means of a fine wire, or by a spark gap. The term electrical thermometer is a misleading one; for as we shall show, the quick movement of the manometer gauge is not due to heat.

At first we passed the discharges through very fine wire. The gauge, which consisted of a bent glass tube containing an index of bichromate of potash, rose suddenly at each discharge and returned approximately to the zero point. When, however, the wire had been heated by repeated discharges, the index showed a slow rise in temperature. Even when the terminals in the glass tube were connected by a fine wire, a very strong electrostatic field was created in the tube. This is shown in an interesting manner by fig. 1 (Plate V). This photograph was obtained by stretching a fine wire over a photographic plate and sending a single discharge through the wire, there being no spark gap in the circuit. The fine wire vibrated during the discharge; and when the negative thus obtained was closely examined, subsidiary vibrations were shown by many black lines approximately parallel to each other. These lines were apparently caused by the heat of the discharge melting the gelatine where the wire came in close contact with the film. The electrostatic field about the wire is exhibited by a fern-like discharge at right angles to the wire.

We were soon convinced that heat played a subordinate part in the phenomenon shown by the quick rise of the manometer index. This rise was apparently dependent upon the electrostatic conditions rather than upon thermodynamic or magnetic phenomena. We, therefore, abandoned the fine wire connection and employed a spark gap having a range from zero to eighty centimeters. It was possible to still further extend this range to two hundred centimeters; but it was found that the range from zero to eighty centimeters exhibited the main features of the phenomenon. The following table gives the results obtained with discharges produced by three million volts, 10,000 Planté cells, 150 condensers, charged in multiple and discharged in series; pointed brass terminals in large glass cylinder; gauge consisting of a bent glass tube with a potassium bichromate index; R_1 and R_2, readings of gauge before and after discharge; D, difference of these readings in centimeters; F, distance between terminals.

It will be seen from the curve A, fig. 2, that the explosive effect increases closely proportional to the length of the spark until the length of fifty centimeters is reached. It then begins to diminish. This decrease occurs with the increase of electrostatic effect in the field surrounding the spark gap,—or in other words, with the divergence or spreading of the electric lines of force. The electrostatic effect in this field, when a difference of potential of three million volts is generated, is very great. Sparks can be drawn from neighboring objects. Shocks are felt when the observers touch each other; and photographic plates, shielded from light in plate holders, held at distances of five or six feet from the terminals, exhibited, on development, brush discharges, or Lichtenberg figures.

F	R_1	R_2	D	Average.
10	4·4	4·9	·5	
“	4·6	5·0	·4	0·45
17	4·5	5·5	1·0	
“	4·7	5·2	·5	
“	4·8	5·5	·7	
“	5·0	6·2	1·2	0·9
24	4·7	6·0	1·3	
“	5·	6·2	1·2	
“	5·3	6·5	1·2	1·2
31	4·8	6·7	1·9	
“	4·8	6·6	1·8	
“	5·4	7·2	1·8	1·8
38	4·7	6·7	2·0	
“	5·1	7·3	2·2	
“	5·5	7·7	2·2	2·1
46	4·8	7·2	2·4	
“	5·3	7·7	2·4	
“	5·5	7·9	2·4	
				2·4
53	5·1	7·3	2·2	
“	5·4	7·7	2·3	
“	5·6	7·3	2·7	
“	5·2	7·1	1·9	
“	5·4	7·5	2·1	2·2
60	4·7	6·2	1·5	
“	5·7	7·3	1·6	
“	5·4	7·6	2·2	
“	5·5	8·1	2·6	
“	5·2	7·1	1·9	
“	5·2	7·6	2·4	
“	5·2	7·5	2·3	2·1
67	4·8	7·0	2·2	
“	5·1	7·1	2·0	
“	5·3	7·3	2·0	
“	5·5	6·7	1·2	
“	5·2	7·1	1·9	
“	5·4	7·3	1·9	
“	5·5	7·6	2·1	1·9
74	4·8	6·4	1·6	
“	5·1	6·6	1·5	
“	5·3	6·9	1·5	
“	5·3	7·3	2·0	
“	5·4	7·2	1·8	
“	5·5	7·3	1·8	1·7
80	4·8	5·2	·4	
“	4·5	6·3	1·8	
“	5·0	5·9	·9	
“	5·1	5·4	·3	1·1

The measurements were next repeated, while, at the same time, spark discharges were measured in a transformer circuit, the primary of which was in the circuit of the high tension transformer or Planté machine. In the following table column A contains the length of spark in the primary circuit, or circuit of the Planté machine; column B, the length of spark in the secondary coil circuit.

A	B	A	B
0	2·5	14	3·0
1	2·7	16	2·8
2	3·0	20	2·6
3	3·0	30	1·7
4	3·0	40	1·8
5	3·0	50	1·6
6	3·2	60	1·3
7	3·3	70	1·2
		80	1·2
			1·

When these results are plotted the lower curve, B, fig. 2, shows that the spark-length in the secondary circuit increases while the primary spark-length is increased up to seven centimeters. When, however, the primary spark-length is increased to fourteen centimeters, the length of the secondary spark begins to diminish. Thus the maximum of the curve B is a little in advance of the minimum of the curve representing the explosive action. Since the magnetic flux through the little transformer is proportional to the strength of the current in the primary circuit, it is seen that the explosive effect is not due to the heat produced by the current. Previous experiments by one of us had shown* that the apparent resistance of the primary spark did not increase with the length of the spark. The diminution in magnetic flux is due not to increase of resistance in the primary circuit but to a shunting through the air of the current in this circuit. Fig. 1 shows how great this shunting action can be even with closed circuits under the action of high electromotive force. The explosive effect, therefore, we are inclined to attribute primarily to an electrostatic action. When the primary spark gap is small, a silent discharge lowers the difference of potential between the spark terminals. As the distance between these terminals increases, the silent discharge diminishes, and the difference of potential increases until a point is reached at which strong inductive efforts take place between all surrounding objects.

The energy of the electrostatic field thus manifests itself by what we may, perhaps, term an ionization and electrical attraction and repulsion of the particles of the air. This electrostatic action does not extend to the great distances reached by the electromagnetic effect of the field. While the latter can be detected many miles, the electrostatic effect is confined to a few feet. Thus a spark of six or seven feet in length (180 to 210 centimeters) is vastly inferior to one of two or three inches (5 to 7·5 centimeters) for the purposes of wireless telegraphy. In experiments with electric waves by means of coherers we found that the electrostatic effect was very disturbing up to a distance of twenty feet from the spark terminals, when these terminals were six feet apart. The disturbance diminished as the terminals were brought nearer together. The minimum of the curve representing this disturbance coincided with the minimum of the curve representing the explosive effect. On the other hand, the action of the magnetic waves on the coherer becomes regular beyond a distance of about twenty feet.

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* Proc. American Academy of Arts and Sciences, vol. xxxiii, No. 24.

The electrostatic effect is evidently some function of the electrical density on the terminals of the spark gap and on the coatings of the condenser. The following experiments illustrate this dependence of the sparking distance upon this density. A chronograph cylinder was provided with two pointers S and S', fig. 3, one of which was connected to one coating of a condenser C, while the other coating of the condenser was joined to the metal cylinder of the chronograph. The coatings of the condenser were charged through an adjustable very large liquid resistance by means of ten thousand cells B. The other pointer was connected with one terminal of a small Ruhmkorff coil I, while the other terminal wire of the coil was led to the cylinder of the chronograph. The primary of the Ruhmkorff coil was interrupted by a second pendulum which broke the circuit at S. The pointers were placed on a carriage. When this was released, the pointers drew lines on blackened paper, fig. 4, placed upon the chronograph cylinder; and the number of the discharges of the condenser in one second could be estimated. With small resistance between the battery and the plates of the condenser the number of discharges in a second was very great. This number decreased as the resistance increased, and was approximately inversely proportional to this resistance. The condensers were of glass, of rubber, and an air condenser was also employed. In every case the number of discharges was inversely proportional to the resistance between one plate of the condenser and the battery.

Since the frequency of the discharge of the condenser depended upon the resistance between one plate of the condenser and the battery, it was evident that the energy of the battery was employed to charge the condenser to a sufficient surface density to enable a spark to be formed. A portion of this energy was wasted. This silent discharge can be regarded as a species of ionization. The condenser with its terminals forms a species of voltaic cell with a phenomenon of polarization. If the capacity of the condenser was increased, the effect was the same as that produced by increasing the resistance, as far as diminishing the number of discharges in a second. The energy of each discharge in this case was not similarly diminished, since the entire strength of the battery served to charge the condensers.

In the phenomenon of the explosion produced by electrical discharges we are, therefore, dealing with electrostatic effects rather than with heat phenomena; and very high potentials bring to light in a marked way the phenomena of the electrostatic field. With differences of potential above one million volts ordinary air becomes a fairly good conductor. The electric force diminishes much more rapidly with the distance than the magnetic force (shown by Hertz). Phenomena of light are produced in the electrostatic field; and there are movements of molecules which may be embraced under the broad term ionization.

We are, therefore, led to the following conclusions:

1. The explosive effect of electrical discharges is due to an electrostatic effect rather than to a heat effect.

2. A strong analogy exists between the terminal conditions existing in electrical discharges and those of the electrodes of an ordinary voltaic cell. The electrical density on the terminals of a condenser is proportional to the strength of current which the charging battery is capable of producing.

3. The electrostatic field, diminishing much more rapidly with the distance than the electromagnetic field, doubtless has its energy consumed in molecular movements.

Jefferson Physical Laboratory,
Harvard University, U. S.

ART. XXVII.—*Experiments relative to the Constitution of Pectolite, Pyrophyllite, Calamine, and Analcite;* by F. W. CLARKE and GEORGE STEIGER.

IN a series of investigations by Clarke and Schneider which were carried out in the laboratory of the United States Geological Survey between 1889 and 1892,* a number of reactions were examined which shed some light upon the constitution of several natural silicates. The work then begun was unfortunately interrupted for several years; but it is now resumed, with the hope that it may be pushed considerably further.

Two of the reactions studied by Clarke and Schneider were of peculiar interest. First, in the case of talc, it was found that one-fourth of the silica could be liberated by ignition; and that the fraction thus set free was measurable by solution in aqueous sodium carbonate. This reaction suggests that other acid metasilicates may behave in a similar way, and that we perhaps have a means of discrimination between such salts and other compounds which simulate them. In other words, an acid metasilicate may be experimentally distinguished from a pseudo-metasilicate by the way in which it splits up when ignited. Evidence bearing upon this supposition will be found in the present paper.

The second of the reactions just referred to is that between dry ammonium chloride, at its temperature of dissociation, and various silicates.† This involves, in part at least, the action of dry gaseous hydrochloric acid upon the compounds which are studied; and different minerals are very differently attacked. Some are almost completely decomposed, others are affected but slightly; and here again there seems to be a method of diagnosis which deserves further attention. Both reactions suggest the main purpose of the investigation; which is, the fractional analysis of silicates by means of various reagents, in order to gain evidence bearing upon their chemical structure. The evidence at least is of value, whether the interpretation of it be right or wrong. Each fact helps to the ultimate solution of the central problem, the problem of constitution.

Pectolite.

The pectolite which was chosen for examination was the well-known radiated variety from Bergen Hill, N. J. The mineral was in long white needles, and apparently quite pure;

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* This Journal, III, vol. xl, pp. 303, 405. 452; vol. xlii, p. 242; vol. xliii, p. 378.

† Bulletin No. 113, U. S. Geological Survey, p. 34.

but the analysis shows that it contained some carbonate as an impurity. Enough of the material was ground up to furnish a uniform sample for the entire series of experiments, and the work properly began with a complete analysis. The results obtained are as follows:

	Analysis.
SiO_2	53·34
Al_2O_3	·33
CaO	33·23
MnO	·45
Na_2O	9·11
Total H_2O	2·97
CO_2	·67
	100·10

	Fractional water.
Water at 105°	0·27
" " 180°	0·16
" " 300°	0·22
" " redness	2·32
	2·97

All of the water was given off at a barely visible red-heat; and the figures show that practically all of it is constitutional; a fact which perhaps hardly needed reverification. The analysis gives the accepted formula for pectolite,

$$HNaCa_2Si_3O_9.$$

Does this represent, as is commonly assumed, a true metasilicate? If it does, we should expect that ignition would split off silica proportional to the acid hydrogen, or one-sixth of the total amount. To answer this question several portions of the pectolite were sharply ignited, to complete dehydration, and then boiled each for fifteen minutes with a solution of sodium carbonate containing 250 grams to the liter. In the extract so obtained the silica was determined; and three experiments gave the following percentages:

8·96
8·67
8·42

Mean, 8·68

One-sixth of the total silica is 8·89 per cent; and the experiments, therefore, justify the original expectation. The belief that pectolite is a metasilicate is effectively confirmed.

Upon the unignited pectolite the sodium carbonate solution has a slow decomposing action, both silica and bases being withdrawn. In two experiments fifteen minutes of boiling extracted 2·07 and 2·55 per cent of silica, and by a treatment lasting four days 4·80 per cent was taken out. With water alone similar results were obtained; the action being so rapid, although relatively slight, that pectolite, moistened, gives an immediate and deep coloration with phenol phthalein. By boiling the powdered pectolite with distilled water alone, 1·65 per cent of silica was brought into solution, and the ignited mineral, similarly treated for fifteen minutes, gave 1·78 per cent. The extraction in these cases is really an extraction of alkaline silicate; as the two following experiments prove. In A the unignited pectolite was boiled for fourteen hours with distilled water; and in B the mineral after ignition was subjected to like treatment for four hours. The dissolved matter in each case was determined, with the subjoined results:

Extracted.	A.	B.
SiO_2	2·98	3·03
CaO	·30	·10
Na_2O	·81	1·50
	4·09	4·63

In A, no simple ratio appears; but in B the extracted silicate approximates very nearly to the salt $Na_2Si_2O_5$. In each instance the ratios vary widely from those of the original mineral, showing that actual decomposition and not a solution of the pectolite as such has occurred.

In the experiments upon pectolite the heating with dry ammonium chloride was omitted, for the data are already given in the original paper by Schneider and Clarke. In their experiments the mineral was thrice heated with ten times its weight of the reagent to above 350°, and then leached out with water. In the solution 20·50 per cent of lime and 6·95 of soda were found, with part of the manganese; showing that a very considerable decomposition had taken place. Possibly, by repeated treatments with ammonium chloride a complete decomposition might be effected; but this question is one upon which it seemed unnecessary to spend further time.

Pyrophyllite.

The empirical formula for pyrophyllite, $AlHSi_2O_6$ is apparently that of an acid metasilicate, and the mineral is therefore peculiarly available for fractional analysis. The compact variety from Deep River, N. C., was taken for examination, and a uniform sample was prepared. Analysis gave the following results:

SiO_2	64·73
TiO_2	·73
Al_2O_3	29·16
Fe_2O_3	·49
MgO	trace
Ignition	5·35
	100·46

If now, pyrophyllite is an acid metasilicate it should break up on ignition in accordance with the equation

$$2AlHSi_2O_6 = Al_2Si_3O_9 + SiO_2 + H_2O.$$

That is, one-fourth of the silica, or 16·18 per cent, should be liberated. The mineral itself is very slightly attacked by boiling with the sodium carbonate solution, and in an experiment of this kind only 0·72 per cent of silica was dissolved. Upon ignition under varying circumstances the following data were obtained:

Ignited ten minutes over a Bunsen burner, and then extracted with sodium carbonate solution, 1·51 per cent of SiO_2 dissolved.

Ignited fifteen minutes over a Bunsen burner, 1·89 per cent became soluble.

Ignited ten minutes over a Bunsen burner and then fifteen minutes over the blast, 2·84 per cent of silica was liberated.

These results are of a different order from those given by pectolite and talc, and raise the question whether pyrophyllite, despite its ratios, is a metasilicate at all. So far as the evidence goes, it may with propriety be regarded as a basic salt of the acid $H_2Si_2O_5$, and its formula then becomes

$$Si_2O_5 = Al-OH.$$

This formula is at least as probable as the metasilicate expression, which latter rests upon assumption alone. Still other formulæ, but of greater complexity, are possible; but until we know more of the genesis and chemical relationships of pyrophyllite, speculation concerning them would be unprofitable.

By heating with dry ammonium chloride, pyrophyllite is very slightly attacked. In two experiments it lost in weight 6·17 and 6·30 per cent respectively. The excess of loss over water is due, as we have proved, to the volatilization of a little ferric and aluminic chloride. The residue of the mineral after this treatment contained no chlorine, so that no chlorhydrin-like body had been formed. The formation of such a compound, the replacement of hydroxyl by chlorine, would, if it could be effected, be a valuable datum towards determining the actual constitution of the species.

Calamine.

The simplest constitutional formula for calamine, the one which is generally accepted, represents it as a basic metasilicate, $SiO_3=(ZnOH)_2$. In this the hydrogen is all combined in one way, and so, too, is the zinc. In all other possible formulæ, simple or complex, the hydrogen as well as the zinc must be represented as present in at least two modes of combination; a condition of which, if it exists, some evidence should be attainable. Our experiments upon calamine have had this point in view; and we have sought to ascertain whether water or zinc could be split off in separately recognizable fractions. Our results, in the main, have been negative, and tend towards the support of the usual formula; but the data are not conclusive, although they seem to be worthy of record.

The beautiful, white calamine from Franklin, N. J., was selected for study, and gave the subjoined composition:

	Analysis.
SiO_2	24·15
Al_2O_3, Fe_2O_3	·19
ZnO	67·55
CaO	·12
H_2O	7·95
	99·96

	Fractional water.
At 100°	·27
" 180°	·22
" 250°	·75
" 300°	·88
Incipient red heat	4·46
Full red heat	1·37
	7·95

Here no clear and definite fractionation of the water is recognizable, at least of such a character as to suggest any other than the ordinary formula for calamine.

Upon boiling powdered calamine with water, practically nothing went into solution, but by boiling with the solution of sodium carbonate, 0·25 per cent of silica was dissolved. After ignition at a red heat, only 0·14 per cent of silica became soluble in sodium carbonate, and after blasting, only 0·24. In these experiments a very little zinc was dissolved also; but there was no evidence that any breaking up of the mineral into distinguishable fractions had occurred. In a hot ten per cent solution of caustic soda both the fresh and the ignited calamine dissolve almost completely; but boiling with aqueous ammonia seems to leave the mineral practically unattacked. All experiments aiming to extract a definite fraction of zinc while leaving a similar fraction behind, resulted negatively.

By heating with dry ammonium chloride, calamine is vigorously attacked, and gains in weight by absorption of chlorine. In two experiments the mineral was intimately mixed with three times its weight of powdered salammoniac, and heated in an air-bath for several hours to a temperature somewhat over 400°. A large part of the residue was soluble in water, and the percentage of this portion, together with the percentage increase in weight, is given below.

	I.	II.
Gain in weight	27·60	25·78
Soluble in water	53·23	67·13

A conversion of calamine into the chlorhydrin, $SiO_2(ZnCl)_2$ would involve a gain in weight of 15·34 per cent. Complete conversion into $2ZnCl_2+SiO_2$ implies an increase of 38·14 per cent. The figures given lie between these two; and are indefinite also for the reason that there was volatilization of zinc chloride.

In two more experiments the calamine, mingled with three times and four times its weight of ammonium chloride respectively, was heated for an hour and a half to bright redness in a combustion tube. The zinc chloride which was formed, volatilized, and was collected by suitable means for determination. It corresponded to 59·6 and 59·0 per cent of the original mineral, calculated as zinc oxide; which indicates a nearly complete decomposition of the calamine into $2ZnCl_2+SiO_2$. The residue was mainly silica, with a small part of the zinc, about half of the silica being soluble in sodium carbonate solution. Here again no definite fractionation of the mineral could be observed.

Finally the action of dry hydrogen sulphide upon calamine was investigated. The mineral was heated to redness in a current of the gas, and gained perceptibly in weight. The percentage data, reckoned on the original calamine, were as follows, in two experiments:

	I.	II.
Gain in weight	6·00	6·43
SiO_2 soluble in Na_2CO_3	16·45	20·95
Sulphur in residue	----	24·12

Complete conversion of calamine into $2ZnS+SiO_2$ implies a gain in weight of 5·80 per cent; and it is therefore evident from the figures of the second experiment that the limit of change was approached very nearly. The 24·12 of sulphur taken up is quite close to the 26·53 per cent which is required by theory. About eight-ninths of the calamine had undergone complete transformation. Again, no definite fractionation was detected.

The hydrogen sulphide reaction was examined still further with reference to the temperature at which it becomes effective. Even in the cold, calamine is slightly attacked by the gas, but its action is unimportant until the temperature of 400° is approximated. Then it becomes vigorous and the reaction goes on rapidly. A few experiments with willemite showed that it also was attacked by hydrogen sulphide, but less vigorously than calamine.

Analcite.

Analcite, from many points of view, is a species of peculiar interest, and of late years it has received a great deal of attention. Its formula may be written in various ways, especially as regards the interpretation of its one molecule of water; but evidence too often has yielded before pre-conceived opinion. Additional evidence is now available, partly from the experiments of Friedel, and partly from the data obtained during the present investigation.

The analcite examined by us was in well-developed crystals from Wasson's Bluff in Nova Scotia. A uniform sample was prepared, as usual, and the analysis, given below, is contrasted with the theoretical composition required by the accepted empirical formula $NaAlSi_2O_6 . H_2O$.

	Found.	Calculated.	Fractions of water.	
SiO_2	57·06	54·55	At 100°	·58
Al_2O_3	21·48	23·18	" 180°	1·16
Fe_2O_3	·13		" 260°	3·64
CaO	·16		" 300°	1·57
Na_2O	12·20	14·09	Low redness	1·90
H_2O at 100°	·58		Full redness	·11
" over 100°	8·38	8·18	Blast	none
	99·99	100·00		8·96

The fractional water determinations were made by heating in an air-bath to constant weight at each temperature up to 300°, and finally over the direct flame. The first fraction, at 100°, is evidently hygroscopic or extraneous water, which can be disregarded. The remainder of the water, 8·38 per cent, belongs to the species. The significance of the analytical figures will be considered later.

Upon boiling the powdered analcite with sodium carbonate solution, 250 grams to the liter as in all the preceding experiments, 0·73 per cent of silica was extracted. After ignition the mineral in two determinations yielded 1·46 and 1·38 per cent respectively. The splitting off of silica is therefore very slight; and one of the formulæ proposed by Doelter,* $Na_2Al_2Si_2O_8+2H_2SiO_3$ may be set aside as improbable. Metasilicic acid or an acid metasilicate can hardly be present in analcite; although the possibility of a neutral metasilicate, as indicated by the empirical formula, is not excluded. By Doelter's formula one-half of the silica ought to be removable.

Upon heating analcite with dry ammonium chloride, results of a remarkable character were obtained. Sodium chloride was formed, which could be leached out by water and measured; while ammonia, free from chlorine, was retained by the residue to a notable and surprisingly stable degree. The experiments in detail were as follows:

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* Neues Jahrb., 1890, i, 133.

A. Analcite, mixed with four times its weight of ammonium chloride, was heated for four hours to 350°. There was a gain in weight of 2·18 per cent, and 6·10 per cent of soda, or one-half of the total amount, was converted into NaCl, which was leached out by water, examined as to its purity, and weighed. In the residue 1·20 per cent of silica was extractable by sodium carbonate, showing that no more splitting off had occurred than was previously observed. The gain in weight, as will be seen from subsequent experiments, is due to the fact that all of the NH_4Cl had not been driven off; or else that more water was retained.

B. Analcite was ground up with four times its weight of NH_4Cl, heated for several hours, reground with another four-fold portion of chloride, and heated to 350° for 21 hours. Gain in weight, 0·08 per cent. 5·57 per cent of soda was extracted as chloride.

C. Analcite heated to 350° for 8 hours, with four times its weight of NH_4Cl. Loss of weight, 0·10 per cent.

D. Six grams of mineral and 28 of chloride, mixed by thorough grinding, was heated to 350° for 14 hours; then was reground with 28 grams of fresh NH_4Cl and heated for 35 hours. Loss of weight, 0·13 per cent. 5·07 per cent of soda was extracted as chloride; plus 0·14 of ammonium chloride unexpelled. 2·03 per cent of silica was rendered soluble in sodium carbonate.

So far, three facts are noticeable. First, the weight of the mineral after treatment is almost exactly the same as before; showing that gains and losses have balanced each other. Secondly, little silica has been split off. Thirdly, approximately, but not rigorously, one-half of the soda has been converted into NaCl. In A, it was exactly half; in the other experiments, a little less than half. Furthermore, in the sodium chloride dissolved out there is only a very little ammonium chloride, amounting at most to 0·14 per cent, calculated upon the weight of the original mineral.

In the residue of the analcite after extraction of sodium chloride, abundant ammonia can be detected, with either no chlorine or at most a doubtful trace. If, however, the unleached mineral, still retaining its sodium chloride, be heated strongly, say from 400° up to redness, NH_4Cl is regenerated and given off. Its absence, as such, both from the leach and the residue was repeatedly proved. The ammonia and water retained by the analcite after heating to 350° with ammonium chloride were several times determined; and the following percentages, still reckoned on the original mineral, were found:

	NH_3.	H_2O.
In B	2·03	2·25
" C	2·19	2·00
" D	2·36	1·89
" "	2·35	----
" "	2·06	----
Mean	2·20	2·04

Correcting the ammonia for the 0·14 of NH_4Cl found in D, the mean value becomes 2·15. This permanent ammonia is not given off upon warming the material with caustic soda solution; and is therefore not present as a salt. The determinations of it were made by three distinct methods, and there is no possible doubt as to its presence and character.

The composition of the analcite after the treatment with ammonium chloride may now be considered, with the subjoined combination of the data. The NaCl in A, 11·50 per cent, was in material which had gained 2·18 per cent, and is subject to a correction which reduces the figure to 11·26. In B, C, and D the corresponding correction is so small that it may be neglected. The last column gives the composition of the leached residue, recalculated to 100 per cent, after deduction of NaCl and the soluble silica. The letters refer back to the several experiments, and the little iron is included with the alumina.

	A.	B.	C.	D.	Average.	Residue.
Sol SiO_2	1·20	----	----	2·03	1·61	----
Insol. SiO_2				54·96	54·96	62·59
Al_2O_3				21·37	21·37	24·34
CaO				·16	·16	·18
NaCl	11·26	10·50	----	9·57	10·44	----
Na_2O				7·12	7·12	8·11
NH_3	----	2·03	2·19	2·21	2·15	2·46
H_2O	----	2·25	2·00	1·89	2·04	2·32
				99·31	99·85	100·00

The analcite residue, like the original mineral, is completely decomposible by aqueous hydrochloric acid. It may be a mixture; but it seems more probable that it is a definite compound; for it approximates in composition to the formula

$$H_2Na_2Al_4Si_8O_{24} . NH_3.$$

This represents a quadrupled analcite formula, in which half of the sodium is replaced by hydrogen, and with NH_3 in place of $4H_2O$. The analytical comparison is as follows:

	Found.	Calculated.
SiO_2	62·59	61·46
Al_2O_3	24·34	26·12
CaO	·18	....
Na_2O	8·11	7·94
H_2O	2·32	2·30
NH_3	2·46	2·18
	100·00	100·00

The agreement is not close, but it is close enough to be suggestive, and to indicate the character of the reaction which has taken place. It needs, however, verification by additional experiments upon other preparations, and upon analcite from other sources. In this connection it may be well to reiterate that the substance was prepared by very long heating at 350°, and is therefore stable at that temperature.

An interesting feature of these experiments is their harmony with the researches of G. Friedel,* who has shown that the water of zeolites may be replaced by ammonia and other substances, without change of the crystalline structure. In the case of analcite, ammonia was taken up to the extent of 2·04 per cent; or almost exactly the amount found in our analcite residue. The great difference between Friedel's method of experimentation and ours, renders the agreement all the more striking; and sustains our belief that the mineral and the residue are compounds of the same general order. We hope to continue our experiments and to extend our investigation to other zeolites.

If, now, analcite and its derivative, our analcite residue, are analogous compounds, the relation between them is expressed by these formulæ:

Analcite .... $Na_4Al_4Si_8O_{24} . 4H_2O$.
Analcite residue............ $H_2Na_2Al_4Si_8O_{24} . NH_3$.

That is, the minimum molecular weight assignable to analcite is represented by four times its empirical formula. Other interpretations of the evidence are possible, but this appears to be the simplest. The water of analcite, as Friedel has shown, must be regarded as water only, not as hydroxyl; for it can be expelled by heat without destruction of the crystalline nucleus, the anhydrous salt, and is taken up again from moist air.

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* Bull. Soc. Min., xix, 94, 1896.

But whatever its mode of union may be, the amount of water corresponds to the simple molecular ratio which is indicated in the formula of the species. One molecule of analcite holds a certain definite number of water molecules; and Friedel's observations are not incompatible with the idea that these are retained with varying degrees of tenacity. This idea is suggested by the various series of fractionation experiments which have been made from time to time, by independent workers, even though the data are not by any means concordant. Thus Lepierre* found that half the water of analcite was driven off at or below 300°, the other half above 440°. In our own experiments three-fourths were expelled at 300°, the remaining fourth being held up to a much higher, but undetermined temperature. In both series the water fractions are representable by fourths; but Friedel's experiments† indicate a continuity of loss in weight of quite a dissimilar order. Friedel holds that all of the water fractionations heretofore made upon analcite are fallacious, and that no definite fractions can be identified, a conclusion strongly supported by his own data, even though the proof is not absolutely positive. The most that can be said is, that the weight of evidence, so far, is in favor of Friedel's contention, but that additional investigation is necessary in order to reconcile all discrepancies. The full significance of the water in analcite remains unknown.

In order to discuss the constitution of analcite, let us recur to the analysis of the mineral itself. It is at once evident from the comparison made on a preceding page that our sample of the mineral varies notably in composition from the requirements of theory. The silica is two and one-half per cent too high, while alumina and soda are correspondingly low. No probable impurity and no presumable errors of manipulation can amount for so great a divergence. If we consult other analyses, as we find them tabulated in manuals like those of Dana and of Hintze, we shall find other cases resembling this, and also examples of variation in the opposite direction, with silica low and an apparent excess of bases. Most analcite gives quite sharply the metasilicate ratios required by the accepted formula; but the variations from it are large enough, common enough and regular enough to command attention. The analyses are not all covered by the recognized theory; and the apparent irregularities are not fortuitous, but are systematic in character.

One explanation of the seeming anomalies is simple and clear. If analcite, instead of being a metasilicate, is really a mixture of ortho- and trisilicate, then all of the analyses become intelligible. In most cases the two salts are commingled in the normal ratio of one to one; but in our analcite the trisilicate predominates, while in some other samples the ortho-salt is in excess. All reduce alike to the simple expression

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* Bull. Soc. Chim. (3), xv, 561, 1896.

† Bull. Soc. Min., xix, 363, 1896.

$$NaAlX\,.\,H_2O,$$

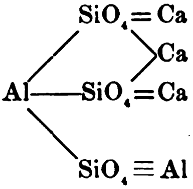
in which X represents $nSiO_4+mSi_3O_8$; a formula which agrees with evidence from various other sources.

For example, analcite may be derived in nature either from albite, $AlNaSi_3O_8$, or nephelite, $AlNaSiO_4$, and on the other hand alterations of it into feldspars have been observed. Its closest analogue, leucite, has yielded pseudomorphs of orthoclase and elæolite; while leucite and analcite are mutually convertible each into the other. The evidence of this character, the evidence of relationship between analcite and other species, is varied and abundant; and the simplest conclusion to be drawn from it is that which has been given. Every alteration, every derivation, every variation in the composition of analcite, points to the same belief. The consistency of the data cannot well be denied.

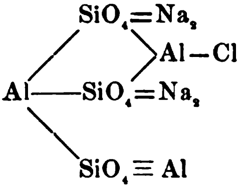
In the case of a normal analcite, that is, one which conforms to the usual empirical formula, the expression which best represents these relations is

$$Al_4Na_4(SiO_4)_2\,(Si_3O_8)_2\,.\,4H_2O;$$

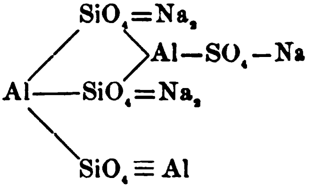
and this accords with the minimum molecular weight as determined by the study of our ammoniated residue. Structurally, this is comparable with the formulæ of garnet, zunyite, sodalite, nosite and leucite; all of which are also isometric in crystallization. The more important of the symbols are as follows:



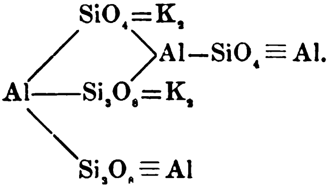
Garnet.



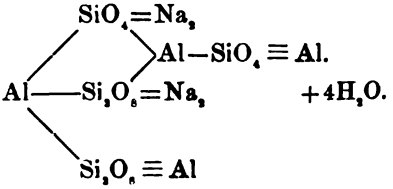
Sodalite.



Nosite.



Leucite.



Analcite.

That is, analcite and leucite become members of the garnet-sodalite group of minerals, and their relations to nephelite, albite, prehnite, natrolite, etc., natural and artificial, are perfectly clear. In analcite there may be admixtures of strictly analogous ortho- or trisilicate molecules; but these remain to be separately discovered.

Now these formulæ are not ultimate verities to be blindly accepted. They are simply expressions which represent composition and a wide range of established relationships, and which serve a distinct purpose in the correlation of our knowledge. Properly used, with due recognition of their limitations, they are helpful, and suggest possibilities of research; misused, they may become mischievous. They now satisfy all known conditions; and that is a sufficient warrant for their existence.

U. S. Geological Survey, July 1, 1899.

Art. XXVIII.—*On Color-vision and the Flicker Photometer;* by Ogden N. Rood, Professor of Physics in Columbia University. Part I.

In the matter of color-vision, there seems to have been a tacit assumption that all persons could be divided into two classes, those with normal vision, and the color-blind. Holmgren's test with colored worsted classifies them in this way, and analogous tests give a like result. According to this view, the color-vision of persons free from color-blindness has generally been considered to be alike. Some time ago, for the purpose of comparing my own color-vision with that of others, an extensive set of experiments were made with the flicker photometer,* and while it turned out that not a single person agreed with *me*, it also was found that no two persons agreed with each other. These divergences were so large that it was impossible to attribute them to errors of observation, and the application to them of a control method showed them to have a real existence.

In making these determinations eleven persons were finally selected, most of them being young men, and all of them having claims to the possession of normal vision or varieties of it. Two were young women, and two, men in middle life. I started originally with fourteen persons, but was quickly obliged to reject three for previously unsuspected abnormality; two of these cases will be considered at the close of this article; the third, which is peculiar, is still under investigation. In comparing the eleven selected persons with myself, it was soon found that they could be divided into two classes with regard to their preception of green, five in one, six in the other, but as far as I could see, there was no especial reason for giving preference to one class above the other. It was accordingly decided to adopt the mean color-vision of the eleven, as representing, for the time being, standard human vision for color, and the divergence of each person from this standard was then calculated.

This standard color-vision is conveniently indicated by 100, in the cases of red, green and violet-blue light. 100 was also taken as the maximum attainable in each case, as these experiments did not deal with the general sensitiveness of the eye to light, but with its relative sensitiveness to light of different colors. That is to say, in the case of the color-curve of each person, the *highest* ordinate, whatever it may be, is set equal to 100, the others falling where the observations indicate on this assumption. Indeed there is no other way of making the calculations, without the aid of supplementary experiments of a totally different character. This much being premised, the tables given below will be intelligible. Classes A and B are given separately for the convenience of the reader, though as before said I do not know of any reason for giving preference to one over the other; indeed it will be noticed that they are more or less blended together by the cases of Wade, Parker and White.

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* See this Journal, Sept. 1899, p. 194.

Class A.

	Red.	Green.	Violet blue.
Wade	97·7	97·4	100·
Trowbridge	100·	91·6	95·6
Dr. Hallock	100·	90·9	96·2
Miss Furness	97·9	90·8	100·
Curtis	90·5	86·6	100·
Miss M	100·	81·6	99·

Class B.

	Red.	Green.	Violet blue.
White	96·1	100	95·8
Parker	95·7	100	95·8
Dr. Dennett	93·8	100	91·5
Dr. Tufts	89·9	100	87·8
Dr. Day	82·9	100	93·3

It may be remarked that all the persons above mentioned are unusually abstemious in the use of alcohol, tea, coffee, and tobacco, and the person who is most deficient in red does not use these articles at all.

It is true that the above results have been obtained by the aid of a standard derived from only eleven persons, all, apparently, with what has heretofore been called normal vision: of course it would be desirable to extend the observations to a larger number of persons, but in the meanwhile it is quite evident that the standard here adopted is considerably better than if one of the eleven had been selected, hap-hazard, as a representative of normal vision. It also follows that anyone of the eleven, when furnished with his curve, becomes a secondary standard, and can correct his observations till they are in accord with the standard here adopted. These results also make it evident, that no one, man or woman, is qualified to do reliable quantitative color-work until his or her color-vision has been tested as above indicated. Certain discrepancies in the older determinations may find here a partial explanation, the remainder, of course, being due to the employment of the older photometric methods.

Below are the results for three cases of red color-blindness, two of which were not previously suspected. All three persons were quite unable to stand the Holmgren worsted test.

	Red.	Green.	Violet blue.
J. Alsberg..........	30·3	88·1	100·
Mr. W...............	35·6	85·5	100·
Mr. O.	35·3	100·	93·9

Older persons appear to be more or less subject to another kind of defect in their color-vision, due, as Dr. Noyes suggests, to a yellow coloration of the crystalline lens. I have not studied the subject much, and can give the result of only one case: it was obtained by the use of the standard above described.

Red.	Green.	Violet blue.
100	77·2	72·

ART. XXIX.—*The Iodometric Determination of Gold;* by F. A. GOOCH and FREDERICK H. MORLEY.

[Contributions from Kent Chemical Laboratory of Yale University—LXXXVIII.]

IN a recent attempt to measure small amounts of gold in solution by titrating with sodium thiosulphate the iodine set free in the action of an excess of potassium iodide upon auric chloride, Peterson* has been led to conclude that, on the average, one-half more thiosulphate is used up in changing the characteristic starch iodide blue to the faint rose color which precedes entire bleaching than is called for upon the theory that the thiosulphate is simply converted to the tetrathionate in the usual manner. Peterson explains the anomaly upon the hypothesis that, besides acting upon the free iodine, the thiosulphate is used up coincidently by interaction with the aurous salt, formed in the reduction, with formation of a gold sodium thiosulphate on the type of the well-known silver sodium thiosulphate. The reaction of this hypothesis is in the nature of things most improbable, since there is no reason to suppose that the soluble double thiosulphate could resist the action of the free iodine which is present to the end—the appearance of the rose color,—and our study of the reaction of sodium thiosulphate upon the mixture of gold chloride and potassium iodide, the account of which follows, discloses no evidence of the consumption of more thiosulphate than is demanded by the usual theory, which postulates the simple formation of the tetrathionate by the interaction of the thiosulphate and free iodine.

It appeared in the course of our preliminary experimentation that, while practically similar results were obtained by adding the thiosulphate until the blue of the starch iodide had changed to rose, the indications were somewhat more concordant when the final rose color was developed by adding iodine to the solution from which the blue had been bleached to colorlessness by a slight excess of the thiosulphate.

It appeared, also, that the reduction of the auric salt, with the consequent liberation of iodine, is conditioned by the volume of the solution, the mass of the iodine present, and the time of action.

The following statement, in which each result is the average of several titrations in close agreement, shows the effect upon the immediate evolution of iodine brought about by adding varying amounts of water to the gold solution before introducing the iodide, and the effect of different amounts of iodide at different dilutions.

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* Zeitschr für Anorg. Chem., xix, 63.

	Potassium iodide.					Gold chloride.	Volume before the addition of the thio-sulphate.
	0·01 gm.	0·02 gm.	0·05 gm.	0·1 gm.	0·2 gm.	0·00087 gm.	cms.
Sodium thiosulphate, $\frac{N}{100}$ nearly cm³.	0·81	0·81	0·81	0·82	0·84	"	15
	0·77	0·78	0·80	0·81	0·81	"	25
	0·74	0·72	0·78	0·79	0·80	"	50
	0·61	0·61	0·68	0·76	0·79	"	100
	0·45	0·49	0·60	0·72	0·75	"	200

It is evident that for the smaller amounts of iodide the liberation of iodine decreases rapidly with the dilution. The larger amounts at the highest concentration show readings a trifle above the normal—perhaps because the well-known effect of concentrated solutions of a soluble iodide upon the delicacy of the starch end-color begins to appear. At volumes lying between the limit of 25^{cm^3} and 50^{cm^3} 0·1 grm. of potassium iodide is an appropriate amount to use; at a volume of 15^{cm^3}, 0·01 grm. to 0·05 grm. of the iodide will do the work; and at lower dilutions, as will appear in the tabular statements to follow, even less of the iodide is effective.

In the series of experiments of which the details are given in Table I, use was made of a solution of pure gold chloride containing 0·8710 grm. to the liter—as determined by careful precipitation in the usual manner by ferrous sulphate, and by an alkaline solution of formaldehyde according to the method of Vanino.* A nearly centinormal solution of iodine was prepared by diluting to a liter 100^{cm^3} of nearly decinormal iodine in potassium iodide carefully standardized against exactly decinormal arsenious acid. A nearly centinormal solution of sodium thiosulphate (containing 1·7012 grm. of $Na_2S_2O_3$ to the liter) was made by diluting to a liter 100^{cm^3} of a nearly decinormal solution of that reagent which had been standardized carefully against the standard iodine prepared as described. The solution of potassium iodide employed contained 10 grm. of that salt in the liter.

In conducting the experiments, a convenient amount of the solution of gold chloride was drawn from a burette, potassium iodide was introduced in the amounts indicated (always several times the theoretical equivalent of the gold, and more than enough to dissolve the aurous iodide precipitated at first), a sufficiency of clear starch indicator was added, the starch blue was bleached by the thiosulphate, and the iodine was added until the liquid assumed a faint rose color. Upon the theory that potassium iodide sets free two atoms of iodine for every molecule of auric chloride (or every atom of gold) present, and that the thiosulphate acts only upon the free iodine to form the tetrathionate in the usual manner, every cubic centimeter of the thiosulphate solution used in the reaction after deducting the amount equivalent to the iodine introduced to get the end-color, should represent

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* Ber. d. d. chem. Gesellsch., xxxi, 1763.

$$\frac{197\cdot3}{2(158\cdot22)}\times 0\cdot0017012 = 0\cdot001061 \text{ grm. of gold.}$$

TABLE I.

Gold chloride = 0·8710 to 1 liter.
Sodium thiosulphate, nearly $\frac{N}{100}$, = 1·7012 " "
Iodine, nearly $\frac{N}{100}$, = 1·3697 " "
Volume at beginning of titration, approximately 50^{cm^3}.

	$AuCl_3$ taken. cm^3.	KI taken. grm.	$Na_2S_2O_3$ used. cm^3.	Gold found. grm.	Theory for gold. grm.	Error. grm.	Per cent.
(1)	5	0·05	4·02	0·00426	0·00435	−0·00009	2·1
(2)	"	"	4·01	0·00425	0·00435	−0·00010	2·3
(3)	"	"	4·06	0·00431	0·00435	−0·00004	0·9
(4)	"	"	4·07	0·00432	0·00435	−0·00003	0·7
(5)	"	"	4·04	0·00428	0·00435	−0·00007	1·6
(6)	10	0·08	8·17	0·00867	0·00871	−0·00004	0·5
(7)	"	"	8·15	0·00864	0·00871	−0·00007	0·8
(8)	"	"	8·16	0·00865	0·00871	−0·00006	0·7
(9)	"	"	8·15	0·00864	0·00871	−0·00007	0·8
(10)	"	"	8·19	0·00869	0·00871	−0·00002	0·2
(11)	"	"	8·46	0·00897	0·00871	+0·00026	3·0
(12)	"	"	8·24	0·00874	0·00871	+0·00003	0·3

Plainly, these results accord reasonably with the theory that two molecules of the thiosulphate are the equivalent in this reaction of two atoms of iodine and one atom of gold. There is no evidence whatever of the excessive action affirmed by Peterson.

The strength of the standard solutions used in the experiments described was such that an error of $0\cdot01^{cm^3}$ in reading the volumes used would correspond to an error of 0·00001 grm. of gold. It is not to be expected that such readings can be trusted ordinarily to a higher degree of accuracy than $0\cdot02^{cm^3}$. In case all three solutions should be read to this limit of accuracy with the errors of all lying in the same direction, the summation of error would correspond to 0·00006 grm. of gold.

In the following experiments, therefore, solutions obtained by properly diluting those of the previous series were employed. The use of a more dilute solution of gold obviated the necessity for diluting the mixture of gold chloride and the iodide before titrating with the thiosulphate. It was found, however, that when the $\frac{N}{1000}$ solution of iodine is employed a correction of 0·1$^{cm^3}$ for volumes not exceeding 30$^{cm^3}$ becomes necessary—the amount required to bring out the rose color in blank tests containing no gold. After the introduction of 0·1$^{cm^3}$ of $\frac{N}{1000}$ iodine into a mixture of potassium iodide and starch indicator of volume not exceeding 30$^{cm^3}$, a single drop of the gold solution—equivalent to 0·000002 grm. of gold—gave a distinct rose color: before such adjustment of the solution five drops—equivalent to 0·000010 grm. of gold—were needed to develop the same color.

TABLE II.

Gold chloride = 0·0871 to 1 liter.
Sodium thiosulphate, nearly $\frac{N}{100}$ = 1·7012 " "
Iodine, nearly $\frac{N}{100}$, = 1·3697 " "

Solution of gold chloride not diluted before mixing with potassium iodide.

A

	$AuCl_3$ taken. cm³.	KI taken. grm.	$Na_2S_2O_3$ used. cm³.	Gold taken. grm.	Gold found. grm.	Error. grm.
(1)	10	0·01	0·83	0·00087	0·00088	+0·00001
(2)	10	0·01	0·83	"	0·00088	+0·00001
(3)	10	0·01	0·80	"	0·00085	—0·00002
(4)	10	0·02	0·84	"	0·00089	+0·00002
(5)	10	0·02	0·88	"	0·00093	+0·00006
(6)	10	0·02	0·82	"	0·00087	0·00000
(7)	10	0·02	0·88	"	0·00093	+0·00006
(8)	10	0·02	0·83	"	0·00088	+0·00001
(9)	10	0·10	0·80	"	0·00085	—0·00002
(10)	10	0·10	0·82	"	0·00087	0·00000
(11)	10	0·01	0·83	"	0·00088	+0·00001
(12)	9	0·01	0·73	0·00078	0·00077	—0·00001
(13)	8	0·01	0·65	0·00070	0·00069	—0·00001
(14)	7	0·01	0·58	0·00061	0·00061	0·00000
(15)	6	0·008	0·51	0 00052	0·00054	+0·00002
(16)	5	0·008	0·41	0·00043	0·00044	+0·00001
(17)	4	0·005	0·35	0·00035	0·00037	+0·00002
(18)	3	0·005	0·24	0·00026	0·00026	0·00000
(19)	2	0·003	0·21	0·00017	0·00022	+0·00005
(20)	1	0·003	0·10	0·00009	0·00011	+0·00002

TABLE II (continued).

B

Gold chloride = 0·0871 to 1 liter.

Sodium thiosulphate, nearly $\frac{N}{1000}$ = 0·17012 " "

Iodine, nearly $\frac{N}{1000}$ = 0·13697

	$AuCl_3$ taken. cm³.	KI taken. grm.	$Na_2S_2O_3$ used. cm³.	Gold taken. grm.	Gold found. grm.	Error. grm.
(21)	10	0·01	8·39	0·000871	0·000890	+0·000019
(22)	9	0·01	7·45	0·000784	0·000790	+0·000006
(23)	8	0·01	6·30	0·000697	0·000668	−0·000029
(24)	7	0·008	5·50	0·000610	0·000583	−0·000027
(25)	6	0·008	5·12	0·000523	0·000543	+0·000020
(26)	5	0·005	4·23	0·000435	0·000449	+0·000014
(27)	4	0·005	3·38	0·000348	0·000358	+0·000010
(28)	3	0·003	2·55	0·000261	0·000270	+0·000009
(29)	2	0·003	1·71	0·000174	0·000181	+0·000007
(30)	1	0·003	0·90	0·000087	0·000095	+0·000008

These results run on the whole as regularly as could be expected, and the use of the dilute standard solutions is obviously of advantage.

In the practical application of any such process for the determination of gold, the elementary form of that metal is the natural starting point. To get the metal into solution with chlorine water or mixed hydrochloric and nitric acids is an easy matter, but the removal of the excess of the oxidizer by evaporation without reducing some auric chloride to the aurous form is difficult. We have found, however, that the free chlorine may be removed from a solution of auric chloride, without reducing the auric salt, by treatment of the solution with ammonia in excess, boiling gently, acidifying with hydrochloric acid and heating if necessary to redissolve the precipitate by ammonia, again treating with ammonia and heating, and once more acidifying. On the second addition of ammonia no precipitation usually takes place with the amounts of gold which we have thus handled, perhaps because enough ammonium chloride has been found to hold it up.

The following table contains determinations made with such a solution of pure gold leaf—tested gravimetrically as to purity.

Obviously, this method, which rests upon the hypothesis that sodium thiosulphate acts in the normal manner only upon the iodine set free by the interaction of gold chloride and potassium iodide, offers trustworthy means for the determination of small amounts of gold.

TABLE III.

Gold chloride made by dissolving 0·0104 grm. of pure gold in the manner described and diluting to 200$^{\text{cm}^3}$.

Sodium thiosulphate, nearly $\frac{N}{1000}$, = 0·17012 to 1 liter.
Iodine, nearly $\frac{N}{1000}$ = 0·13697 " "
Potassium iodide = 10 grms. " "

Portions were treated with the potassium iodide without previous dilution.

	AuCl$_3$ taken. cm^3	KI taken. grm.	Na$_2$S$_2$O$_3$ used. cm^3.	Gold taken. grm.	Gold found. grm.	Error. grm.
(1)	1	0·005	0·55	0·000052	0·000058	+0·000006
(2)	1	0·005	0·55	0·000052	0·000058	+0·000006
(3)	2	0·005	1·06	0·000104	0·000112	+0·000008
(4)	2	0·005	1·08	0·000104	0·000114	+0·000010
(5)	5	0·01	2·45	0·000260	0·000260	0·000000
(6)	5	0·01	2·50	0·000260	0·000265	+0·000005
(7)	5	0·01	2·45	0·000260	0·000260	0·000000
(8)	5	0·01	2·50	0·000260	0·000265	+0·000005
(9)	5	0·01	2·50	0·000260	0·000265	+0·000005
(10)	10	0·02	4·86	0·000520	0·000515	—0·000005
(11)	10	0·02	4·85	0·000520	0·000517	—0·000003
(12)	10	0·02	4·90	0·000520	0·000520	0·000000
(13)	10	0·02	4·80	0·000520	0·000512	—0·000008
(14)	10	0·02	4·84	0·000520	0·000516	—0·000004

ART. XXX.—*The Mineralogical Structure and Chemical Composition of the Trap of Rocky Hill, N. J.*; by ALEXANDER HAMILTON PHILLIPS, D.Sc.

Introduction.

THE Mesozoic trap rocks, or trap dikes of the eastern coast of the United States, are almost entirely confined to a comparatively narrow strip of country, in which the Triassic formation appears at the surface. The two seem to be so constantly connected, that almost every isolated Triassic area, however small, is accompanied with its corresponding intrusions of trap.

The Triassic strata of the Atlantic coast extend in a northeast and southwest direction from Nova Scotia to North Carolina, through an interrupted course, and are found more or less in isolated patches along the western portion of the coastal-plain, and lying next the older crystalline schists of the Appalachian range, into and through the border of which the trap dikes also extend.

In size, these dikes vary from a foot or so in thickness to such large masses as are represented by the Palisades of the Hudson. Their direction, especially of the larger masses, conforms in a marked degree to the strike of the strata in which they lie, and owing to their greater power of resisting erosion, they appear on the surface as parallel ridges, which mark the transition from the low level country of the coastal-plain to the higher foot-hills of the Appalachian Range.

Throughout this entire area of some twelve hundred miles in extent, the mineralogical composition of the trap is wonderfully alike, as has been pointed out from results of analyses of this rock from localities widely separated.[1] *

The specific gravity of these traps varies, from data collected by J. D. Dana,[2] from 2·94, that of the Palisades, to 3·16, that of a specimen from North Carolina; while there are cases in which the specific gravity falls as low as 2·83.[3] 3·16 still seems to be the maximum.

The mineralogical constituents were generally supposed to be magnetite, augite and labradorite. G. W. Hawes[4] was the first to show the complex character of the feldspars, from analyses made of specimens of the West Rock, at New Haven, and of the New Jersey Palisades. Campbell and Brown later pointed out other complexities than that of the feldspars, and a specimen from Milford, N. J., is described as a hypersthene-diabase[6]; as well as an olivine-diabase from Virginia.

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* See references given on p. 285.

Magnetite, augite and labradorite may be considered as the most widely distributed and characteristic minerals of the Triassic traps, and, from the constant occurrence of small percentages of P_2O_5 in all analyses, apatite might be added to these three. The above is, however, by no means a complete list of primary minerals which occur locally, for added to these, olivine, anorthite, hypersthene, biotite, pyrite, and zircon are local minerals, given here in the order of their frequency.

The minerals of contact and decomposition, or of secondary formation, are well known and have a well deserved reputation from their beauty and perfection of crystalline form; they have found their way into all collections.

Description of the Rocky Hill Dike, and its relation to the Sedimentary Strata.

In its relation to the sedimentary strata, the Rocky Hill dike is no exception to the rule, lying well up in the strata, which represent the Triassic beds, and especially so at either of its extremities.

The Triassic has been divided here into three divisions[6]: the Stockton, Lockatong and Brunswick shales; the Stockton being the lower and older in the series, lying just above the crystalline gneiss.

The Rocky Hill trap extends for some fifteen miles in a northeast and southwest direction through these beds of shale, lying for the most part within the Brunswick shales, to the strike of which it seems to conform for about six miles west of the village of Rocky Hill, where it makes a slight curve, and breaks through the strata extending to a higher horizon in the Brunswick shales; at this bend the ridge reaches its highest elevation, Mount Rose possessing an elevation of 415 feet, as given in the New Jersey Geological Report. From this point it gradually declines in height eastward, until the ridge entirely disappears at the country level east of the Pennsylvania railroad. One mile east of Rocky Hill village it divides into two branches; one extends east, the other north towards Griggstown, this branch being much the smaller of the two in extent, and separated from the easterly one by a formation known as the Sand Hills. Whether these two branches are connected by a sheet of trap underlying the Sand Hills as suggested by N. H. Darton,[7] produced by an upward folding of the trap is difficult to prove, although from consideration of the whole lay of the strata, this seems very probable.

The surface occupied by the trap is thickly strewn with large irregular, though somewhat rounded masses of rock in different stages of decomposition. The resistance offered by the basic traps of this formation to atmospheric weathering is very marked, in contrast to acid dikes; the acid dikes weathering much faster than the enclosing sedimentary rocks,[*] leaving long channels, while the basic traps are prominent as ridges. The soil lying between the surface boulders and derived from them by decomposition is never very deep. In quarries, that portion lying at the surface has a reddish appearance, caused by the oxidization principally of the ferrous iron contained in the augite. This surface weathering does not extend to depths much greater than ten feet, in the rock mass itself; individual crystals in macroscopic specimens from depths greater than this seem perfectly fresh. The disintegration reaches much greater depths along joints and cracks. In the quarry at the Hopewell end of the dike an entirely different decomposition has taken place, much of the rock mass here exposed is soft and chloritic in nature, and has taken up 3 per cent of water; some specimens show even more than this, and well crystallized calcite and zeolites appear in the cracks and joints.

In width the Rocky Hill dike does not vary much from a half mile. Along the Mount Rose road, which crosses it at a right angle, it measures 860 feet. Along the gorge of the Millstone River, which also cuts through it at Rocky Hill village at nearly a right angle, it measures 4000 feet, and if we take into consideration the dip of the enclosing strata, to which it seems to conform at these points, its thickness measured at right angles to the dip at Mount Rose would be 250 feet, at the Millstone 1200 feet. That the dip of the enclosing strata is conformed to, at least in the middle section of the dike, is proven, in lack of evidence shown by direct contact, by the baked condition of the shales lying on the north or upper side, in contrast to those lying on the south or under side. The shales lying on the north from near Griggstown to Mount Rose having been brought in close contact with the liquid magma, have been semifused and upon cooling crystallized in some cases, but generally developing spilosites in large quantities. In particularly favorable localities, such as north of the canal bridge at Rocky Hill, the dark green crypto-crystalline nodules reach their largest size, being in some cases three-quarters of an inch in diameter. These nodules do not appear to exist at all on the south side of the dike, and the explanation seems to be, that the shales resting directly upon the molten mass have suffered far greater baking than those underneath, for if the dike were vertical we should expect an equal baking on both sides, which, indeed, is the case west of Mount Rose, where the trap dike no longer conforms to the strike of the shales, but breaks up through them, its surface area becoming very much narrowed in consequence.

At several points in the fused shales well crystallized epidote and tourmaline have been found, and especially at the Griggstown copper mine, where very perfect crystals of black tourmaline completely fill some specimens of the shale. They are hemimorphic, showing the hexagonal prism with fine longitudinal striations, terminated at one end by the rhombohedra $(02\bar{2}1)$ and $(10\bar{1}1)$, the antilogous pole being more complicated. Here also amygdaloid cavities were found, one of which was 1·3 inches in length, with walls thickly studded with well-formed crystals of epidote, calcite and a yellow mica, probably chalcodite.

Macroscopic Description.

At the village of Rocky Hill, the Millstone River cuts through the trap ridge at nearly a right angle, forming a gorge 150 feet deep; along the eastern side of this gorge the Rocky Hill Stone Storage Company has opened three quarries, located in different positions of the dike, as related to a vertical cross-section. No. 1 is near the lower side, 480 feet from the contact border; No. 2 is near the middle of the dike, 1350 feet from No. 1, and No. 3 420 feet from the upper contact and 1600 feet from No. 2. These distances are only approximate, as the upper and lower contacts cannot be made out definitely. Quarry No. 2 is the only one worked at present, rock being taken out and crushed for road and ballasting purposes. Each of these three quarries represents a different phase of the rock, not only in macroscopical appearance, but also in the chemical composition of the mineral constituents, as well as in the analyses of the rock as a whole.

Specimens near the contact with the shale have a very fine, granular, almost massive structure, appearing to the eye homogeneous, except here and there, where light is reflected from an almost microscopical cleavage face of a feldspar crystal; otherwise the boundary rock, and especially on the lower side, is a dark, slate-blue color, massive and compact, showing no cavities or schistose structure. Passing in from the crypto-crystalline border region, when quarry No. 1 is reached, the rock has assumed the characteristic texture of an ordinary dolerite; here it presents a coarse-granular appearance, in which its two prominent minerals, feldspar and augite, are easily distinguished; as the aggregation of feldspar crystals proceeds, the color of the rock is less dark, and specimens from quarry No. 2 appear much lighter than any others. Here the augite crystals reach a length of ⅜ of an inch. In this region there is a well-defined schistosity developed, produced by the parallelism of the long axis of the augite crystals. The excellent cleavage of these crystals gives a decidedly easy fracture along this direction, to the entire rock mass. This easy fracture is taken advantage of by the workmen in splitting out blocks for street paving.

There can be distinguished in the coarse variety, dark, irregular, highly lustrous though small aggregates of magnetic oxide of iron. The size of these aggregates increases with the coarseness of the specimen.

Scattered throughout the entire mass are very minute crystals of chalcopyrite, too scattered to form a factor in the analyses of the rock. In some rare localities they have been segregated into masses, as much as half an inch in diameter. It may be mentioned here that copper minerals are found at several localities along the contact of the trap and the shale, especially at Griggstown, where a small quantity of ore has been taken out in the form of silicate and carbonates.

The structure found in quarry No. 2 represents the conditions which are found throughout the greater portion of the dike, from the Millstone River westward. Eastward the coarseness decreases, due undoubtedly to the fact that erosion has not exposed the deeper, more central and coarser portions. Quarry No. 3 represents the maximum coarseness and differentiation of the rock's components, for here, as is afterwards shown from the analyses, the composition is the farthest removed from the original magma, as represented by the composition of the microcrystalline band along the contact. The aspect of the rock has changed, due to two primary causes. In the first place, this is due to the elongation of the diallage-like augite crystals, measuring often an inch, and occasionally two inches in length. With its excellent cleavage and metallic schiller, it forms a very striking feature, while the schistose arrangement marked in quarry No. 2 has been lost here, probably the pressure to which it was due having been removed or relieved by smaller secondary dikes, though a diligent search of the locality has failed to reveal them. There are some small dikes northeast of the Rocky Hill trap, though their connection with it is not apparent. Judging from the perfection of the crystals of diallagic augite, there could at the best have been no very great disturbance, as they have suffered but slight distortion, their long axis being but slightly curved, and showing no displacements.

In the second place, the color of the feldspar has changed from white to a very light flesh color, which certainly indicates a change in its nature, which is also brought out in the analyses. That portion of the dike which presents these characteristics is limited to a small area, and nowhere outside of quarry

No. 3, or its immediate vicinity, are crystals of like perfection and size found. It is also remarkably near the upper contact border, and judging from its differentiation, coarseness and crystalline perfection as compared with other portions of the dike, it must have been subjected to slower cooling, and has been the last portion to consolidate, or might have been in close contact with the source from which the molten magma was forced out, and consequently nearer the source of heat. This would explain the slower cooling, but not the difference in composition, which specimens from these three localities show.

The shales just above this point show an extensive baking, for it is here that the spherulites reach their maximum, both in number and size, indicating that they have been subjected to a more intense heat, or one of longer duration.

Microscopical Description.

Microscopically, the groundmass shows the absence of glass, and is therefore holocrystalline. In the finest grained portions the feldspars are present in the characteristic lath-shaped crystals, metasilicates lying between them, in the form of fine crystalline aggregates of grains or wedged-shaped anhedrons, each having a different crystallographic orientation.

This structure, with the absence of glass, following the classification of Iddings[9] for these rocks, is that of a dolerite or diabase, in contrast to the basalts, in which glass is present in the groundmass.

Magnetite, being one of the primary minerals, and characteristic of these diabases, is found liberally represented in sections from all portions of the dike; and in those from the contact-band, subject to more rapid cooling and crystallization, magnetite is evenly distributed as fine irregular grains, showing no crystalline boundaries, except in a few cases where octahedral outlines appear. Since the magnetite is not found as inclusions in the feldspars, but is contained in everything else except in the apatite, the formation of the mineral in the magma has been subsequent to that of the feldspars. The conditions favorable for its separation have been of considerable duration, as the relative quantity contained in the dike has increased in sections from coarser specimens, as from quarry No. 3; here the masses of magnetite have reached such a size as to form a macroscopic feature of the rock. Some of these larger masses completely enclose feldspar crystals as well as apatite, which appears in hexagonal sections in an otherwise completely dark field of magnetite.

Qualitatively all the magnetite gives very strong reactions for titanium, and judging from this it must carry nearly if not all the one per cent. or more of the titanic oxide found in the rocks.

While magnetite is one of the first minerals to separate from a magma on cooling, the relation of the magnetite to the other minerals in the sections, enclosing feldspars, apatite, and even augite, being wedged in between other crystals in the sections, would indicate that its separation has been a slow, continuous one, and since its relative quantity increases in that portion of the dike which we believe has been the last to consolidate, there have been changes in the magma favorable to this increase. From these facts we would conclude that the magma, after having been intruded between the sedimentary strata, was subjected to a very slow and gradual cooling, and possibly under high pressure, which would also tend to keep the magnetite in solution. That this cooling was slow, and that after injection the magma was subjected to little or no subsequent disturbance, is also brought out by the condition of the apatite crystals, which are everywhere present. In sections from the outer portions, apatite is represented by numerous slender but short needles, which increase in size until in sections from quarry No. 3 they reach a diameter of $\cdot 2^{mm}$ and a length of $1\cdot 5^{mm}$ before disappearing out of the section, being uninterrupted throughout their long axis and extending through adjacent minerals, both magnetite and feldspars. As these are the first crystals to form, any slight disturbance during the slow cooling would have been sufficient to break up this continuity.

Olivine.—The conditions favoring the separation of olivine in the Rocky Hill diabase have been very limited, as crystals of it are very few in number and confined to the border area, but these few present interesting facts when their method of decomposition is considered. They occur as rounded grains for the most part, but few showing an ill-defined crystalline form. The larger crystals, where fresh, are of a light green color, and show a good cleavage as well as irregular fracturing.

In their decomposition they have followed two distinct methods. The first, or earlier one, is by the formation of grains of magnetite, appearing as black granular strings, following all the cleavage cracks and irregular fractures of the crystals; and especially on the border, the black grains have been produced to such an extent as to surround each crystal with a decidedly dark band, and in the case of some of the smaller nodules, this secondary formation of iron oxides has proceeded so far, that the entire body of the crystal is nearly opaque, and might be mistaken for a mere collection of magnetite granules. This method of decomposition of olivine is described by Zirkel[10] in connection with the olivine of gabbros, and furthermore he states that it is never found in connection with the olivine of basalts. Prof. J. W. Judd,[11] in connection with the older peridotites of Scotland, concludes that it is a phenomenon which takes place only at a great depth from the surface, and consequently at considerable pressure. From this we may conclude that originally this trap was buried far below the surface at the time of its intrusion, and has since been elevated to its present position, and the strata originally covering it have been carried away.

The second method of the olivine decomposition is that generally found at the surface, in which an olivine rich in iron, such as this seems to be, by oxidation and formation of small scales of limonite and hematite, becomes dark yellow, brown or red. The greater number, and especially the smaller rounded grains, have become deeply colored by this formation of iron oxide, while the larger, some at least, are still perfectly fresh, with the exception of the magnetite grains. Their rounded shape is due to a partial resolution in the magma, as is shown by the corrosive cavities.[12] There are present, also, large inclusions of glass, so characteristic of olivine. The absence of serpentine as a decomposition product would also point to an olivine with large percentage of iron.

In size the olivines attain a maximum diameter of about .04^{mm}.

Augite.—The crystallization of the diallage-like augite is varied. In slides of the finer or diabase structure, the groundmass is composed of a collection of microscopical crystals, with now and then a lath-shaped section of a larger augite lying among them. In sections at right angles to the $\dot{c}$-axis the characteristic prismatic cleavage is well developed, as is also the cleavage parallel to the orthopinacoid; crystals from quarry No. 1 show a maximum extinction angle of 46°.

These diallagic crystals constantly increase in length as we pass in from the border; in quarry No. 2 they are 8 to 10^{mm} in length; in quarry No. 3 they reach their maximum length. They are all elongated in the direction of the $\dot{c}$-axis, and the pinacoids are developed at the expense of the prism faces, giving them a flattened appearance. The color constantly deepens, and in reflected light they appear about black, except on cleavage faces where a characteristic schiller is developed. The cleavage faces parallel to the prism show the trace of a twinning plane parallel to the orthopinacoid, running directly through the middle of the crystals, each twin being equally developed. This twinning is very constant in the larger crystals, and between crossed nicols, in some instances, polysynthetic twinning is indicated along this line. In transmitted light, their color is uniformly brown, with little pleochroism. Extinction is undulatory, indicating a shell-like structure, the angle of extinction being greater for external than for the internal layers. This angle constantly increases from the fine-grained crystals, where it is 46°, reaching a maximum of 58° in the larger crystals of quarry No. 3. Sections parallel to the vertical axis show a constant structure of fine striations; traces of interposition planes, parallel to the basal pinacoid. These striations appear on all sections which are parallel to the vertical axis, as running across, between the cleavage cracks. They do not appear on sections parallel to the base, neither as lines or dots, which would indicate that they are not fibres, but owe their origin to polysynthetic twinning parallel to the basal pinacoid. Their trace, on sections parallel to $\infty P \grave{\infty}$, makes an angle of about 74° with the trace of the composition face of the twins twinned parallel to $\infty P \bar{\infty}$, when the lines are symmetrical on either side. This would prove these lines to be traces of planes parallel to $0P$, as the angle β for monocline pyroxene is 74° 10′; these very fine interposition planes play an important part in the decomposition of the mineral, as well as in the production of the peculiar schiller. The great number of small inclusions contained in the crystals are symmetrical in regard to the axis, and fall into two groups; those parallel to the vertical axes, and those arranged along the twinning planes, parallel to $0P$. The inclusions are of the nature of cavities filled with hydrated oxides, formed by solution of the crystal body under pressure, as described by Judd, who infers that they are negative crystals, and mark the line of least resistance to solution, and therefore stand in the same relation to the body of the crystal as the etching figures do to the surface or faces. Of the two systems that one in which the long axis is parallel to the $\acute{c}$-axis of the crystal offers the greater resistance to solution, and requires a higher pressure, consequently takes place at greater depths.

This system is the better represented of the two and is very characteristic of sections from the central and upper portions of the dike; they are considerably elongated, and occur in large numbers. If they are secondary formations it would add another proof, that this dike was formed at a considerable depth below the surface. Whether they are secondary formations is very difficult to determine. The matrix surrounding them has not been bleached as if the oxides of iron filling them had been drawn from their immediate vicinity. This is in decided contrast to other granular inclusions, evidently secondary products, found as a result of surface action, in which the body of the crystal presents a decided bleaching.

The formation of these secondary granules begins first at the margin and works its way toward the central portions of the crystal, following cleavage cracks and fractures, and especially along interposition planes running across between the cleavage cracks; following this system, they form parallel lines of fine granules of magnetite, limonite, etc., which seem to be also an important factor in producing the schiller-like luster, and they would evidently be a result of surface action. These secondary granules are very numerous since the percentage of ferrous iron in all these crystals is very high.

As decomposition advances, other products are formed and become mixed with the oxide of iron granules, such as fibrous chlorite, biotite and epidote; even when this has reached such an advanced stage that the original crystal is replaced by a crystalline aggregate, the position of the fine interposition planes of the mother crystal is still marked by lines of dark granules. The oxidation of the large amount of iron contained in the diallage is the first step in the rock's decomposition and has commenced even before the clouding of the feldspars.

Biotite, as a primary mineral, is absent, and is found only as a secondary product derived from the decomposition of the diallage. It is present only in those slides which show the diallage in an advanced stage of decomposition; its formation begins after a considerable amount of the iron has been oxidized.

Quartz.—What has been said of biotite may also be said of quartz, to a great extent, with this exception, that in specimens from quarry No. 3 there are a small number of quartz grains which are evidently primary, judging from their size and the freshness of the surrounding crystals. Secondary quartz is formed in connection with the formation of chlorite in the decomposition of the diallage; this is best represented in the Hopewell quarries, where quartz granules can be picked out of the mass of chlorite.

Amphibole, in the form of hornblende, is represented in a few slides from the central portions of the dike, but is most frequent in all slides from quarry No. 3 and here stands in a very intimate relation and is closely connected with the history of the diallage, from which it has been derived by paramorphism. It occurs in two distinct varieties: one compact, yellow-brown in transmitted light, the other fibrous and light-green, both of which are very pleochroic. In the green variety, the ray vibrating parallel to $\mathfrak{c}$ is decidedly bluish green; that parallel to $\mathfrak{a}$ and $\mathfrak{b}$ yellow. In the compact form, the pleochroism is shown only in shades of brown and yellow; the absorption is very marked, especially in the compact variety, and sections with the light rays vibrating parallel to $\mathfrak{c}$ are very dark. The absorption in both varieties is as usual $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. The prismatic cleavage is perfectly developed and is strikingly in contrast to that of the neighboring diallage crystals. The maximum extinction-angle measured from cleavage cracks in the prism zone was 16°. The compact as well as the fibrous form exists as boundaries to the diallage[13] with their long axes parallel. The fibres are limited to the outer portions of the diallage, while the compact is distributed as patches in the interior of some of the diallage crystals, as well. These interior patches would point rather to paramorphism than to decomposition as the agent to which the hornblende owes its origin. Neither variety would be considered as a primary component.

Feldspars.—In all slides from quarry No. 1 and the border region, the structure of the feldspars is eminently that which is so characteristic of the diabases, being ophitic in contrast to the irregular appearance of feldspar crystals marking the gabbro structure. Both of these structures are perfectly represented in different portions of the dike.

In sections of the finest grained specimens, which appear macroscopically to be almost homogeneous, the feldspars are always well formed, and are always present in lath-shaped sections; their average size is $\cdot 21^{mm}$ in length and $\cdot 046^{mm}$ in width, which will also give a good idea of the fineness of this diabase. Toward the center of the dike, the feldspar crystals constantly increase in size, and by the time quarry No. 1 is reached they have increased to $\cdot 5^{mm}$ in length and $\cdot 15^{mm}$ in width, still presenting very strongly the ophitic structure; in numerous cases, however, there is a strong tendency toward the granular, irregular, or gabbro structure. This is brought about by a shortening of the $\breve{a}$-axis, parallel to which the lath-shaped crystals are elongated.

Twinning after the albite law is common, and generally the smaller crystals are composed of a single pair of twins. As the crystals increase in size, polysynthetic twinning after the albite law is the rule. The large angles of extinction on sections perpendicular to 010, rising to a maximum of 37°, coupled with the double refraction, would indicate a feldspar rich in calcium or one in which the ratio of anorthite to albite was high or of the composition of bytownite. The feldspars of quarry No. 2 upon the whole have a higher index of refraction, and the difference in the interference colors is very marked. The twinning is more extensive and many of the crystals show a decided compound nature. This is brought out by the lamellæ in the central portion of the compound crystals extinguishing at larger angles than the exterior bands, also by the interference colors of the different lamellæ. The central lamellæ are also much narrower, and the lath-shaped form is giving way to granular and irregular-shaped crystals in sections.

In the identification of the feldspars, samples of the powder separated with the Thoulet solution were used, and the angles of extinction on the base in connection with the albite twinning striations or the prismatic cleavage were measured. In the sample with a gravity greater than 2·69, fragments showing the lath-shaped crystals with narrow striations clearly predominated over the fragments of the granular form of crystal with wide twinning laminations. The reverse of this was found to be the case in the sample separated with a gravity less than 2·69.

The compound nature of these five samples is indicated by the difference in the extinction-angles of the several laminæ of which they are composed, so that the separation of feldspars of complex nature is at the best only a coarse assorting, in which the majority of particles will have a composition agreeing with the specific gravity, or will be homogeneous. The fineness to which each particle would have to be reduced to separate these interlaminated feldspars, is far beyond the practicability of separating them with the solution, owing to the slowness with which they settle. The angle of extinction measured on the base was found to vary from −27° to −4°; the lamellæ giving the larger angle were found to be the very narrow, more centrally located. These angles indicate that the analysis of this sample would lie between the composition of Ab_1An_6 on the one side and Ab_1An_1 on the other."[22]

In the sample separated with a gravity less than 2·69, the fragments with the very narrow lamellæ had disappeared. The angle of extinction was found in numerous cases to be almost parallel with the twinning striations, showing that the proportion of anorthite had decreased until the composition is possibly that of oligoclase or andesine. In quarry No. 3 the crystallization of the feldspars is very irregular, and complicated by an increase in the tendency to form, in addition to the twinning after the albite law, numerous twins after the Carlsbad law, showing both straight and irregular contact planes. Numerous patches exhibit the cross hatching produced by the combination of the albite and pericline twinning. The Baveno type is also present in frequent cases. The large masses of feldspar do not give distinct crystalline outlines, being moulded by the surrounding diallage crystals and magnetite, fragments of which they enclose. Their crystallization must have been either at the same time or after that of the diallage. These masses of feldspar preserve the same crystallographic orientation throughout, thus presenting the poikilitic structure common in gabbros."[23]

A large proportion of the feldspars of this locality have become clouded and stained dark by the infiltration of iron from neighboring decomposing diallage; the cloudiness being produced by the first steps in kaolinization.

Chemical Analysis.

In the analysis of the rock, what seemed to be typical specimens from quarries No. 3 and No. 2, and a specimen from the microcrystalline contact region, were selected. These three specimens, it was thought, would represent the three stages in the trap so decidedly different in the development of its crystals, and would also give a good basis, by means of which the magmas from out of which they were crystallized might be compared. The specimen from the border was taken, as the magma must have consolidated upon contact with the sedimentary rock, or at least soon after injection between the strata, and can therefore be held to represent the composition of the entire mass at the time of its intrusion, or its original composition.

In specific gravity these specimens fall in the middle of the series observed in the Mesozoic trap. The average for the entire dike would be about 3. The densities of specimens collected at various localities along the ridge vary between 3·125, the density of a specimen from the Hopewell extremity, and 2·935, the density of one taken near the village of Rocky Hill. The density of the typical rock from quarry No. 2 was found to be 2·968; that of quarry No. 3, 3·023. These variations in density are no more than would be expected, caused by the local change, both in the composition and relative proportion of its primary minerals.

Analyses of the Rocky Hill Trap.

	I. Quarry No. 3.	II. Quarry No. 2.	III. Contact band.	IV.	V.	VI.
SiO_2	56·78	50·34	51·46	52·1	52·53	52·37
TiO_2	1·44	1·56	1·06	....	·32	·21
Al_2O_3	14·33	15·23	13·98	16·7	14·35	15·06
Fe_2O_3........	5·76	2·82	2·66	....	5·93	2·34
FeO..........	9·27	11·17	8·92	12·7	5·45	9·82
MnO	·25	·14	....	....	trace	·32
CaO..........	5·26	9 61	10·49	10·8	10·27	7·33
MgO	1·58	5·81	7·59	3·2	7·99	5·38
Na_2O........	3·43	2·93	4·75	2·3	1·87	4·04
K_2O	1·75	1·02		·8	·97	·92
P_2O_5..........	·36	·20	·17		·15	
					SO_3= .08	
H_2O above 110°	·10	·07	*	1·4 ignition	1·23	2·24
H_2O below 110°	·33	·19	....	....	....	....
	100·64	101·09	101·08	100·	101·14	100·03

* Unfortunately for direct comparison this specimen was dried at 150° before it was analyzed, but the percentage of H_2O must have been small.

Analyses IV to VI of Mesozoic trap are given for comparison; IV is an analysis of Rocky Hill trap, by G. H. Cook; V, by F. A. Genth, from York Co., Pa.; VI, Trap rock at Meriden, Conn., by J. H. Pratt.[15]

Analyses V and VI represent the average composition of the Mesozoic trap of the Atlantic coast, and by a comparison with these analyses, the variation of the Rocky Hill trap from the mean will be apparent. The most important points to be noted are: first, that the Rocky Hill trap is high in alkalis and especially so in potassium, which also becomes concentrated locally in quarry No. 3. This high percentage of alkali is a factor which exercises an important influence in the composition and formation of the various feldspars.

Second, the percentage of iron is high, especially the ferrous iron. The iron as well shows a decided concentration in No. 3. This high amount of ferrous iron produces a diallage remarkably high in FeO, as the analyses will show. While the TiO_2 is very high in comparison with the two analyses given, there are other analyses in which TiO_2 is present in equally as high percentages. In the West Rock, New Haven, there is 1·41 per cent of TiO_2.[16]

In the separation of the various mineral components for analysis, the magnetite was taken out with a small electromagnet, the strength of which was not sufficient to attract the diallage; though diallage in which magnetic granules had developed as a result of decomposition and oxidization of the ferrous iron was removed. After the magnetic portions were removed, the remainder was separated with the Thoulet solution. The diallagic augite separated at the highest specific gravity of the solution; after this trials were made at various stages of dilution, until the specific gravity of the feldspars was reached. Up to this point very little material could be separated, and this, when examined with the microscope, was found not to be homogeneous.

Neither in specimens from No. 2, or from No. 3, was the amount separated above the specific gravity of 2·72, that is after magnetite and diallage had been removed, very large. In the further separation of the feldspars, the solution was diluted to a specific gravity of 2·69, the theoretical density which would separate the two species of feldspars, labradorite on the one side, and andesine on the other[17]; then again diluted to a density of 2·60, separating the anorthoclase from albite. In order to obtain as pure sample as possible of each, for analysis, each specimen was put through the solution several times. While the specific gravities of the feldspars overlap each other to a great extent, still these portions separated will give an idea of their molecular variation in different positions of the dike, i. e. at different steps in the crystallization of the magma.

In the analysis of the diallage-like augite the sample used in No. 2 was separated at the highest specific gravity of the solution. That used in No. 3 was selected by hand, as the crystals were quite large.

Analyses of Diallagic Augite.

	No. 2.	Ratio.	No. 3.	Ratio.	IV.*
SiO_2	47·72	·795	48·54	·809	50·71
Al_2O_3	3·44	·014	5·50	·053	3·55
					(MnO)
Fe_2O_3	5·93	·037	2·77	·017	·81
FeO	18·34	·254	21·25	·295	15·30
CaO	11·40	·205	10·97	·196	13·35
MgO	12·89	·320	7·67	·191	13·63
Na_2O	·86	·013	3·10	·039	1·48
K_2O	·37	·003			
Ignition	·00	....	·82	....	1·17
	100·95		100·62		100·00

No. 2. $R_2O : RO : R_2O_3 : SiO_2$

·016 : 779 : ·051 : 795

No. 3. $R_2O : RO : R_2O_3 : SiO_2$

·039 : 682 : ·07 : 809

From the chemical composition these two pyroxenes lie between the molecule of hedenbergite ($CaFeSi_2O_6$) on the one side and diopside ($CaMgSi_2O_6$) on the other, of which they are isomorphous mixtures[18]; combined with these is a small proportion of the alkali-bearing pyroxene ($NaFeSi_2O_6$). The magnesia-bearing molecule separates out first at higher temperatures, decreasing the percentage of Mg in the rock as a whole; this has been carried to such an extent, that when No. 3 is reached, this locality being the last to consolidate, the percentage of MgO has been reduced to 1·58. The magnesia content has been a decreasing factor from the beginning of crystallization; decreasing from 7·59 per cent in the contact, to 1·58 per cent in No. 3. As the pyroxene is the only magnesia-bearing mineral present, with the exception of olivine in the contact region, the greater portion of this change in per cent of magnesia present is caused by the variation in the pyroxene molecule. The change in the iron-bearing molecule is not so clear, it being obscured by the magnetic oxides, which increase along the same direction as the ferrous component of the pyroxene; what has been lost by the lack of magnesia in the magma has been made up in ferrous iron and alkalis. The tendency is, then, to form pyroxene at the border, rich in magnesia, of the composition of $CaMgSi_2O_6$ when the magma is rich in magnesia, or of the composition of $CaFeSi_2O_6$ when the magma is rich in iron.

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* Augite from West Rock, New Haven, Proc. U. S. National Museum, vol. iv, p. 132.

The calcium in the pyroxene does not seem subject to much change.

There has been an increase in the alkali-bearing molecule, acmite, as the amount of SiO_2 has increased. This increase of the acmite molecule as the acidity of the magma increases, is in accord with the experiments of F. Becke.[19] He points out that the acmite molecule takes part in the composition of monoclinic pyroxene, crystallizing from magmas with a percentage of SiO_2 of 50 or above. With the increase of 6 per cent of SiO_2 from No. 2 to No. 3 there is a decided increase of K_2O and Na_2O found in the pyroxene. Campbell and Brown[6] have shown that in this Mesozoic diabase rich in MgO, where it reaches an amount equal to 12 per cent or more, the orthorhombic pyroxene appears as the mineral hypersthene. We would not expect an orthorhombic pyroxene to appear in the Rocky Hill diabase, as the proportion of (FeO+MgO):CaO in the analysis showing the highest percentages of these, is as 1·7:1, a proportion of FeO and MgO far below the ratio at which it has been found necessary for these to be present, in order that they, in crystallizing, should form an orthorhombic pyroxene. The molecular relation of (MgO+FeO):CaO must be as 3:1 or greater.[20] This high proportion of MgO+FeO is only locally reached in this diabase, and for that reason it is to be expected that the metasilicate is almost invariably some form of the monoclinic pyroxene.

Analyses of Feldspars from Quarry No. 2.

	I.		II.		III.		IV.	V.
					West Rock, N. H.[4]			
	Gravity greater than 2·69.		Gravity < 2·69.		Gravity > 2·69.	Gravity < 2·69.	Gravity 2·703.	Gravity 2·659.
SiO_2 ...	53·84	·899	62·26	1·037	52·84	60·54	53·7	62·
Al_2O_3 ..	29·30	·287	21·87	·216	28·62	24·11	29·6	24·
Fe_2O_3 ..	·81	·005	·54	·003	1·52	1·14	----	----
CaO ...	10·08	·180	6·53	·116	11·81	9·15	11·8	5·3
MgO	·28	·007	·15	·003	·46	·27	----	----
Na_2O ..	5·31	·085	7·98	·128	2·38	4·11	4·9	8·7
K_2O ...	1·16	·012	1·20	·012	·86	1·06	----	----
Ignition	·44	---	·32	----	1·06	·59	----	----
	101·22		100·85		99·75	100·97		

I. Gravity > 2·69. Ratio of

$$R_2O : RO : R_2O_3 : SiO_2 = ·097 : 187 : ·292 : ·899.$$

In this feldspar the albite molecule is to the anorthite molecule as 1 : 1+ or the feldspar is a normal labradorite, which agrees well with the optical properties as found in quarry No. 2.

IV gives the theoretical percentage composition of a labradorite of the proportion of 3 molecules of albite to 4 molecules of anorthite"[21].

II. Gravity < 2·69. Ratio of

$$R_2O : RO : R_2O_3 : SiO_2 = {\cdot}140 : 119 : 219 : 1{\cdot}037.$$

This would represent a feldspar of the composition of albite to anorthite in the proportion of 5 : 2+ and would be that of an oligoclase.

V represents the composition and gravity of an oligoclase of the proportion of 3Ab : 1An."[21]

Feldspars from Quarry No. 3.

	I. Gravity > 2·69.	I. Ratio.	II. Gravity < 2·69.	II. Ratio.	III. Gravity < 2·60.	III. Ratio.	IV. Gravity 2·577.
SiO_2	66·84	1·110	71·68	1·195	66·28	1·104	66·79
Al_2O_3	17·98	·176	15·02	·147	16·79	·164	19·36
Fe_2O_3	2·60	·016	2·48	·015	1·60	·010	·91
CaO	4·02	·071	3·86	·068	·71	·012	·80
MgO	·48	·012	·12	·003	·13	·003	·13
Na_2O_3	5·46	·088	5.52	·076	9·76	·057	7·34
K_2O	1·72	·018	1·37	·014	5·31	·056	4·95
Ignition	·72		·00		·49		
	99·82		100·05		101·07		100·28

$$\text{I. } \left.\begin{array}{l} R_2O : RO : R_2O_3 : SiO_2 \\ 106 : 83 : 192 : 1{\cdot}110 \end{array}\right\} = 9\text{ Ab} : 3{\cdot}5\text{ An.}$$

$$\text{II. } \left.\begin{array}{l} R_2O : RO : R_2O_3 : SiO_2 \\ 90 : {\cdot}71 : 162 : 1195 \end{array}\right\} = 5\text{ Ab} : 2\text{ An.}$$

$$\text{III. } \left.\begin{array}{l} R_2O : RO : R_2O_5 : SiO_2 \\ 213 : 15 : 174 : 1104 \end{array}\right\} = 6\ O_1 : 22\text{ Ab} : 1\text{ An.}$$

$$\begin{array}{c} K_2O : Na_2O \\ 56 : 157 \end{array}$$

IV is the composition of an anorthoclase."[24] In the analyses of the feldspars from quarry No. 3 it was impossible to get good samples, from the fact that they are considerably decomposed and stained by infiltration of iron; in addition to this all the quartz found in this locality will be included in II, and for that reason the percentage of SiO_2 here runs up to 71. While the above analyses cannot strictly be taken to represent the composition of pure feldspars, they will represent, however, the relation of K_2O, Na_2O and CaO in the feldspars of this position in the dike, and will also enable us to make a comparison with the feldspars of No. 2 crystallizing earlier.

Here the normal feldspar is an andesine or oligoclase, replacing the normal labradorite of quarry No. 2. In order to get an estimate of the quantity of each mineral compound of quarry No. 2 and No. 3, a sample of each was taken, crushed finer than $\frac{1}{100}$ inch, and the dust washed out, then separated with the magnet and solution, with the following results, as the magnet was strong enough to remove the secondary oxide of iron granules formed by the decomposition of diallage: in getting the total per cent of diallage this magnetic portion must be considered, but is given separately here.

	Quarry No. 2.	Quarry No. 3.
Magnetite	4·1	6·
Magnetic	3·6	9·7
Diallage	45·6	41·
Feldspar, G. $>$ 2·69	32·2	23·1
Feldspar, G. $<$ 2·69	14·3	13·4
Feldspar, G. $<$ 2·60	0·	6·5

The decrease in the density of the feldspars from No. 2 to No. 3, or their increase in acidity is clearly shown by the above figures. The total feldspars in No. 2 is 45 per cent; 69 per cent of this is denser than 2·69, and 31 per cent lighter than 2·69, while it all falls before the solution reaches the density of 2·60. The total feldspars in No. 3 is 43 per cent, 53·7 per cent is denser than 2·69, and 46·3 per cent below the density of 2·69; of this 67·3 per cent is denser than 2·60, while 32·7 per cent is below the gravity of 2·60.

In the crystallization of the feldspars, the tendency is to form the anorthite molecule at the border region, but that has not been reached, as the optical properties of the crystals in this region are those of a feldspar of the composition of bytownite, a feldspar richer in CaO than any of the samples analyzed; this is also substantiated, as the analyses of the rock in this region indicates a 10 per cent increase in CaO. From the bytownite molecule the amount of CaO has gradually decreased until in quarry No. 3, the last region to consolidate, a feldspar almost free of CaO has been formed, with a large percentage of K_2O. Thus the feldspars of the Rocky Hill dike present a complexity far greater than has yet been noted in connection with the Mesozoic trap.

Conclusion.

1st. The Rocky Hill trap, from its holocrystalline nature, would be classed as a dolerite.

2d. The border region possesses the ophitic development of its plagioclase; if the small amount of olivine present be considered, it would present the structure and composition of an olivine diabase.

3d. The slow cooling to which it has been subjected coupled with tendency of the anorthite molecule to separate at a higher temperature, has concentrated the more acid feldspars in the portion last to consolidate, to such an extent that its mineralogical composition is almost that of a diorite.

4th. From the character of the decomposition of the olivine, and the solution cavities in the diallage crystals, the intrusive nature of this dike is without doubt, as this must have taken place at considerable depths from the surface, and under very heavy pressure.

John C. Green School of Science, Princeton University,
New Jersey, June, '99.

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[2] J. D. Dana, this Journal, 3d series, vol. ix, p. 191.

[4] G. W. Hawes, Proc. U. S. National Museum, vol. iv, 1881, p. 132.

[5] H. D. Campbell and W. G. Brown, l. c., p. 341.

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[15] Mineral Resources of the U. S., 18th, p. 958.

[16] This Journal, vol. ix, 1875, p. 327.

[17] Dana's System of Mineralogy, p. 327.

[18] G. Tschermak, Ueber Pyroxene und Amphibole, T. M. M., 1871-17.

[19] F. Becke; Experimentelle Untersuchungen über die Bildung der Minerale in Magma, T. M. M., xviii, p. 124.

[20] J. H. L. Vogt, Beiträge zur Kenntniss der Gesetze der mineralbildung in Schmelzmassen, etc., Kristiania, 1892.

[21] Dana's System of Mineralogy, p. 327.

[22] See Iddings-Rosenbusch, p. 300.

[23] E. H. Williams, Jour. of Geol., vol. i, p. 176.

[24] Dana's System of Mineralogy, p. 324, No. 8.

Art. XXXI.—*Some Analyses of Italian Volcanic Rocks;* by Henry S. Washington. I.

During the past two years I have made a number of analyses of Italian volcanic rocks, with the intention of incorporating them in a general article on the subject. As, however, other work has come up which will delay this indefinitely, it has been decided to publish them. Isolated analyses of rocks, without discussion of their relations to those of other connected types, are of little use. But they may prove of service to others investigating this region, and personally I would like to clear out this pigeon-hole.

Trachytes of the Phlegræan Fields.—The material composing the cone of Monte Nuovo, which was formed in 1538, is largely pumice and lapilli, but blocks of dense lava from a flow are found in a quarry on the southern slope, and it is from these that material was taken for analysis.

The rock is compact and very fine-grained, with a rough feel. The color is ash gray, with streaks of lighter gray. A few small glistening phenocrysts of alkali-feldspar are visible.

Under the microscope specimens vary considerably, but all belong to the Ponza type of Rosenbusch. The structure is hyalopilitic trachytic. Long slender prisms of alkali-feldspar are abundant, often split and branching as has been described in the case of some Ischian trachytes.* They are elongated parallel to the axis ȧ. Small elongated crystals of ægirine-augite and grains of magnetite are present in less amount. All these, with dusty grains, lie in an isotropic glass-like groundmass, which is usually colorless, but often a light brown, especially in patches. This base gelatinizes readily with HCl, and must be largely composed of the sodalite molecule, since it is the only constituent which could carry the notable amount of Cl found. I could find no trace of the anorthite and olivine mentioned by dell'Erba,† nor of the leucite spoken of by vom Rath‡ as having been found by G. Rose.

The specimen of the Monte Cuma trachyte was obtained from the large quarries at the west foot of the ancient acropolis. It is similar in appearance to the preceding, showing also a eutaxitic structure, though here the streaks are darker, and minute pyroxene phenocrysts are common.

Microscopically it differs considerably from that of Monte Nuovo. Prismatic phenocrysts of alkali-feldspar, elongated parallel to *ă*, are abundant, their borders tending to shade off into the groundmass. Smaller, longish crystals of a pale green, very slightly pleochroic ægirine-augite are very abundant. Few, if any, of the separate individuals of ægirine mentioned by Rosenbusch* could be seen. The groundmass proper is composed of small rude laths and anhedra of alkali-feldspar, with grains of magnetite and ægirine-augite. Interspersed with these are small, colorless, isotropic anhedra, which gelatinize with HCl and stain readily. These must be referred to sodalite, which the analysis shows is present to the extent of about ten per cent. No glass base could be found and the specimen analyzed is quite holocrystalline. A dense, black, glassy obsidian, carrying many feldspar phenocrysts, is also found at the locality in small amount.

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* H. S. Washington, this Journal (4), i, p. 375, 1896.

† dell'Erba, Boll. Com. Geol. Ital., 1894, p. 197.

‡ Vom Rath, Zeitschr. d. d. Geol. Ges., xviii, p. 613, 1866.

Vom Rath speaks of sodalite in the groundmass as "unvollkommen ausgeschieden," and describes the sodalite which occurs in the crevices of the rock. He also mentions a scapolite-like tetragonal mineral as very abundant in the groundmass, and, from his analysis, comes to the conclusion that it has the composition of oligoclase.† My microscopical exami-

	I	II	III	IV	V
SiO_2	60·33	59·79	61·71	59·47	61·23
TiO_2	trace	trace	....	....	....
Al_2O_3	18·74	19·71	16·85	17·24	18·42
Fe_2O_3	2·84	2·95	4·27	4·33	....
FeO	1·29	1·08	....	....	4·55
MnO	trace	trace	trace	....	....
MgO	0·38	0·36	0·99	0·99	0·34
CaO	1·15	1·19	1·51	3·10	1·81
Na_2O	7·15	6·79	7·50	6·17	10·82
K_2O	7·30	7·10	4·36	8·01	2·62
H_2O	0·56	0·24	1·05	1·07	0·16
Cl	0·43	0·53	0·65	1·03	0·78
	100·17	99·74	98·89	101·41	100·73
O = Cl	0·11	0·13	0·16	0·24	0·18
	100·06	99·61	98·73	101·17	100·57

I. Trachyte, Monte Nuovo. H. S. Washington anal.
II. Trachyte, Monte Cuma. H. S. Washington anal.
III. Monte Nuovo. Abich anal. Abich. Vulk. Ersch., 1841 p. 39. Recalculated in Roth. Gest. Analysen, 1861, p. 18, No. 9.
IV. Monte Nuovo. Rammelsberg anal. Roth. Gesteins-Analysen, 1861, p. 18, No. 10.
V. Monte Cuma. Vom Rath anal., op. cit., p. 610.

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* Rosenbusch, Mikr. Phys., ii, 1896, p. 750.

† Vom Rath, op. cit., pp. 608, 612.

nation does not substantiate these observations, nor, from a chemical standpoint, is such an assumption necessary, as will be seen on discussion of the analyses. Vom Rath also describes and figures a fayalite-like olivine which occurs in the crevices. Its occurrence resembles that of fayalite in obsidians of Lipari, described by Iddings and Penfield.*

My two analyses (I and II) resemble each other very closely and are typically trachytic in most features. SiO_2 is about 60, which is rather low for trachytes and approaches the silica content of the phonolites. Al_2O_3 is normal; iron oxides, magnesia and lime are low, with Fe_2O_3 notably higher than FeO in accordance with the presence of the ægirine molecule. The alkalies are high, amounting together to 14 per cent, and molecularly Na_2O surpasses K_2O (the ratios being 1·47 and 1·45), so that both rocks must be held to belong to the sub-group of soda-trachytes.

The two analyses by Abich and Rammelsberg are chiefly of historical interest, since they are obviously at fault in many particulars. That of vom Rath is better, but suffers from a peculiarity elsewhere observed in his rock analyses, viz: too high soda and too low potash.† It was this, together with his higher lime, which led him to infer the peculiar composition of the mineral mentioned above, which may be referred to sodalite, or possibly to marialite. The mineralogical composition of the Monte Nuovo rock cannot be satisfactorily determined, owing to the presence of glass. That of the Monte Cuma trachyte, however, which is holocrystalline, calculates out very nicely from the data given by the analysis and the microscope.

Orthoclase	42·2
Albite	34·4
Sodalite	11·1
Diopside	4·9
Ægirine	6·5
Magnetite	0·9
	100·0

Trachytes of Ischia.—Of these rocks three analyses were made. They are all so well known that a detailed petrographical description seems superfluous. That from Monte Rotaro is the black vitreous rock containing sheaf-like ("keraunoidal") alkali-feldspars already mentioned. The Monte Marecocco lava is light gray with many large phenocrysts of alkali-feldspar, a typically trachytic groundmass of feldspar laths, diopside, ægirine and magnetite grains, and little or no glass. No sodalite could be found, though it is undoubtedly present. The Arso rock is the well-known black one with numerous feldspar phenocrysts. It is notable through its small though constant content of olivine.

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* Iddings and Penfield, this Journal (3), xl, p. 75, 1890.

† Cf. H. S. Washington, Journ. Geol., v, pp. 351, 357, 1897.

	I	II	III	IV
SiO_2	61·62	61·88	60·77	61·49
TiO_2	0·87	0·69	----	----
Al_2O_3	18·24	18·21	19·83	20·02
Fe_2O_3	2·36	2·19	4·14	3·11
FeO	1·28	1·38	2·43	2·72
MnO	trace	trace	trace	0·01
MgO	0·56	0·61	0·34	0·52
CaO	1·44	1·15	1·63	1·88
Na_2O	5·77	6·89	4·90	3·39
K_2O	7·60	6·72	6·27	7·13
H_2O	0·78	0·37	0·24	0·46
Cl	0·15	0·30	----	----
P_2O_5	----	----	trace	0·02
	100·67	100·39	100·55	100·75
O = Cl	0·03	0·07		
	100·64	100·32		

I. Trachyte, Monte Rotaro. H. S. Washington anal.
II. Trachyte, Marecocco. H. S. Washington anal.
III. Monte Rotaro. Fuchs anal. Min. Petr. Mitth., 1872, p. 232.
IV. Marecocco. Fuchs anal. Min. Petr. Mitth., 1872, p. 229.

The two analyses (I and II) resemble each other very closely, except in the alkalies, though the total amount of these is the same. They are typical trachytes rich in soda, and are practically identical with those of the Phlegræan Fields, as was to be expected from the microscopical examination. The rather high TiO_2 is to be noted, as well as the Cl lower than in the preceding. They resemble on the whole the analyses of Fuchs, though his alkalies are considerably lower. It is probable that his alkalies are too low, since calculation shows that about two per cent more are needed to satisfy the SiO_2 and Al_2O_3 present. Analysis II, of the holocrystalline Marecocco trachyte, calculates out as follows. It seems probable that sodalite is rather too high, since it was not seen in the sections.

Orthoclase	39·5
Albite	47·1
Sodalite	4·7
Diopside	4·6
Ægirine	1·4
Magnetite	2·7
	100·0

Analyses of the Arso lava are given below. Mine agrees fairly well with that of Fuchs, though there are certain differences, notably in the alkalies. His analysis of the scoria of this eruption, from Le Cremate, is lower in SiO_2 and higher in Al_2O_3, but otherwise resembles that of the main part of the flow. Abich's analysis differs in several particulars from the others, and is inserted only for the sake of completeness.

This rock differs markedly from the other trachytes of Ischia, which, as Fuchs has shown, have a very uniform composition. It is much more basic, showing lower SiO_2 and alkalies, and higher FeO, MgO and CaO. The sections also reveal the presence of some olivine and considerable basic labradorite. The rock, therefore, is not a typical trachyte, and was placed by me among the group of ciminites recently described.* It, however, does not contain as much MgO and CaO as these do normally, and might better be considered as transitional between them and the normal trachytes.

	I	II	III	IV	V
SiO_2	56·75	57·73	54·83	61·03	57·91
TiO_2	1·24	----	----	----	0·65
Al_2O_3	18·37	17·85	20·17	17·21	15·79
Fe_2O_3	2·22	4·44	4·77	4·84	6·81
FeO	3·04	3·90	3·86		0·01
MnO	trace	----	----	0·17	0·23
MgO	2·02	1·77	1·93	2·07	1·66
CaO	4·68	3·65	4·12	1·43	2·99
Na_2O	4·85	3·67	3·04	4·64	6·01
K_2O	5·92	7·65	7·38	7·16	7·27
H_2O	0·18	0·09	0·46	0·56	0·34
Cl	0·11	----	----	----	0·60
P_2O_5	----	trace	----	----	0·01
	99·38	100·85	100·56	99·11	100·27
O = Cl...	0·03				0·14
	99·35				100·13

I. "Ciminite," Arso, Ischia. H. S. Washington anal.
II. Ditto, Arso. Fuchs anal. Min. Petr. Mitth., 1872, p. 230.
III. Scoria, Le Cremate. Fuchs anal., op. cit., p. 231.
IV. "Ciminite," Arso. Abich anal., Vulk. Ersch., 1841, p. 44.
V. Sodalite-Trachyte, Monte Santo, Naples. Johnston-Lavis anal. Geol. Mag. (III), vi, p. 77, 1889.

In a recent paper† Rosenbusch describes the minerals lining the crevices of this rock, which include alkali-feldspar, sodalite, magnetite, biotite, augite, hypersthene and apatite. He remarks that this association, with the chemical and mineralogical characters of the rock, points conclusively to its relationship with the monzonites and essexites.

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* Jour. Geol., iv, p. 834, 1896 and v, p. 351, 1897.

† Rosenbusch, Ueber Euktolith, etc., Sitz. ber. Akad. Wiss., Berlin, 1899, p. 111, note 1.

In connection with this rock it is interesting to note the composition of the sodalite-trachyte described by Johnston-Lavis, an analysis of which is given in V. The rock occurs west of Naples, near the Phlegræan Fields. It carries sodalite and hornblende, and, although it is not stated to contain olivine, in chemical composition it resembles very much the Arso rock, indicating a similarity in composition and differentiation of the magma at the two centers.

General Relationships.—This is not the place for a general discussion, but a few words may be devoted to the relationship of the rocks whose analyses have just been given to those of the other Italian volcanoes. The apparently justifiable assumption is made that these analyses fairly represent the composition of the rocks of the Phlegræan Fields and Ischia.

It is well known that the main line of Italian volcanoes has erupted rocks which are characterized chemically by high potash and lime, and that leucitic rocks are abundant.* It has also been shown that the rocks of this line belong to two main groups: the leucitic rocks, which are either basic (leucitites and leucite-tephrites) or intermediate (leucite-trachytes), and latites† (intermediate between trachytes and andesites or basalts), characterized by the presence of both orthoclase and plagioclase. In all these rocks the ratio of K_2O to Na_2O is constantly greater than unity, sometimes much so, and CaO is also high.

It is seen from the analyses given in the preceding pages that at Ischia and the Phlegræan Fields the rocks are chemically quite distinct, Na_2O being here constantly higher than K_2O, CaO being low, and leucite absent, or at least very rare.‡ They also tend to be rather high in SiO_2.

While they differ from the rocks of the peninsula, they show certain analogies with the volcanic rocks of the islands which lie along the west coast of Italy,—those of Capraia,§ the Ponza Islands,‖ the Lipari Islands,¶ and perhaps Etna** and the Val di Noto in Sicily.* It is impossible here to go into a description of all these, for which the reader may turn to the references given. It must suffice to state that at Capraia we find andesites, at the Ponza and Lipari† Islands rhyolites, trachytes, latites and a few basalts, while at Etna‡ and Val di Noto there have been erupted only normal basalts of a fairly uniform composition. From the analyses of the rocks of these localities it is evident that they differ also chemically from those of the Bolsena-Vesuvius line, Na_2O being higher than K_2O (except in the rhyolites), though here also CaO is apt to be rather high.

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* Cf. Journ. Geol, v, p. 376, 1897.

† Ransome, this Journal (4). v, pp. 355, 372, 1898.

‡ Leucitic rocks have been observed as blocks in tuff at Monte di Procida and one or two other places in the Phlegræan Fields. They are not abundant, and their relations with the main trachytic rocks are uncertain.

§ H. Emmons, Q. J. G. S., xlix, p. 129. 1893.

‖ Doelter, Denkschr. k. Akad. Wiss. Wien, xxxvi, p. 1, 1875.

¶ Cortese and Sabatini, Descrizione delle Isole Eolie. Rome, 1892.

** v. Lasaulx in vom Waltershausen der Ætna, Leipzig, 1880, ii, pp. 425 ff. Ricciardi, Gazz. Chim. Ital., xi, p. 149, 1881.

Consideration of these facts leads to the conclusion that the rocks of Ischia and the Phlegræan Fields are related rather to those of the other islands than to those of the main Bolsena-Vesuvius line, and, while the data at hand are perhaps insufficient, I would express the view that they are not genetically connected (at least in an immediate way) with the closely adjacent rocks of Somma and Vesuvius.

The idea that a volcanic fracture-line exists west of the Italian peninsula was first broached by Pilla in 1842, supported by Doelter and Suess, expressed in a somewhat modified form by Ponzi, and has lately been taken up by Ricciardi.§ This last writer bases his conclusions partly on stratigraphical observations, but largely in a chemical way on the amount of SiO_2 in the various rocks.

That the amount of SiO_2 alone is not a proper nor sufficient basis on which to compare rocks of various regions is a fact that will scarcely be disputed by any petrographer. But from a broader point of view, embracing all the chemical and mineralogical characters of the various rocks, as well as from other, topographical, vulcanological and stratigraphical considerations, it would seem that the conclusion is justified that a volcanic fracture-line exists west of the coast of Italy and parallel with it, extending from Capraia, through the Ponza Islands, Ischia and the Phlegræan Fields, the Lipari Islands, and ending probably in Sicily at Etna and Val di Noto.

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* Ricciardi, Gazz. Chim. Ital, xl, p. 171, 1881.

† It may be remarked that I have been able to find no good analysis of the well known rocks of these islands, with the exception of one of an apparently abnormal type described by Hobbs (Bull. Geol. Soc. Am., v, p. 599, 1893), those of Abich (Vulk. Ersch., 1841, pp. 25, 62) and of Baltzer (Zeit. d. deut. geol. Ges., xxvii, p. 36, 1875) being too obviously incorrect to merit consideration—a striking instance of the imperfection of our chemical knowledge of igneous rocks.

‡ Johnston-Lavis (Boll. Soc. Ital. Micro. Acireale, i, p. 26, 1888) has detected leucite in one of the basalts of Etna and Bäckström (Geol. Fören. Förh., xviii, p. 155, 1896), in rocks from Volcanello.

§ Ricciardi, Sull' Allineamento dei Vulcani Italiani. Reggio-Emilia, 1887. References to the other authorities cited may be found in this paper, as also a map.

The main vulcanological fact on which this conclusion rests is the similarity between the two lines in the order and direction of extinction along them. Space is lacking for detailed statement, but in both we find the volcanic activity dying away from north to south. Thus the volcanoes of Bolsena and Viterbo are older than those of the Alban Hills, where eruptions took place not much anterior to the earliest Roman times, and perhaps also during the Roman Republic. At the Ernici and Rocca Monfina the evidence is uncertain, but at the southern extremity there is the still active volcano of Vesuvius.

Similarly along the western line we find to the north the much denuded remains of old volcanoes at Capraia, Elba and Giglio. At the Ponza Islands the original forms are better preserved, though extensively denuded. At the Ischian region the forms are more perfect and activity is almost ended, as shown by the eruptions of the Solfatara, Monte Nuovo and Arso, and other facts. At the Lipari Islands we find also the remains of large volcanoes, and activity is still kept up to a certain extent at the small vents of Vulcano and Stromboli.* At Etna alone, near the extreme south end of the line, do we find a typical volcano, in a comparatively perfect state and in full activity,—comparable with Vesuvius.

It may also be noted that there seems to be a tendency for the later lavas to be more basic than the earlier, as has been pointed out in general for the Bolsena-Vesuvius line,† and as may be exemplified by the rocks of the Alban Hills, Vesuvius, Stromboli‡ and Etna.

That the petrographical provinces of the Bolsena-Vesuvius line and of the groups of Ponza, Ischia, the Lipari Islands and Etna are quite distinct is well known,§ but it is less generally supposed or accepted that a well marked line exists—now largely covered by the waters of the Mediterranean—which is parallel to the other and quite distinct from it, and that the rocks of Ischia and the Phlegraean Fields are not genetically connected with those of the neighboring Vesuvian vent.

In this connection it may be suggested as a tentative hypothesis that another parallel fracture-line is to be found to the southwest, which extends from the small islets of Linosa and Lampedusa, southwest of Malta, through Pantellaria to Sardinia. Concerning the first two islets our information is of the scantiest, it being only known that they are volcanic.‖ Rosenbusch[*] has pointed out the close resemblance between the pantellerites of Pantelleria and the commendites of San Pietro on the southwest coast of Sardinia, which, as well as the other rocks of Pantelleria, are high in Na_2O.[†] At the volcano of Monte Ferru[‡] in Sardinia Doelter found the rocks to be trachytes, phonolites and basalts (with some leucite-basalts), which, according to his analyses, show Na_2O (molecularly) uniformly higher than K_2O, and in some cases very high.

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* Cf. Bonney, Volcanoes, 1899, pp. 198–201.

† Cf. Journ. Geol., v, p. 376, 1897.

‡ Cortese and Sabatini, op. cit., p. 84. The rocks of Vulcano are also generally basic, but those of the last eruption are rather acid. (Op. cit, p. 114.)

§ Cf. Bonney, Volcanoes, p. 197.

‖ Scrope, Volcanoes, 1862, p. 345.

It would seem, then, from these rather insufficient and summarily given facts, that we have in the Italian district three parallel volcanic lines. The latest, along the peninsula, is characterized chiefly by high K_2O, as well as high CaO, and by the presence of leucite. The next, that of the islands along the west coast, is also high in alkalies but with Na_2O rather higher than K_2O, and without leucite. The third, which lies far out in the Mediterranean, and which is possibly the oldest, is much higher in Na_2O and seems to be characterized by the presence of peculiar soda minerals, such as ænigmatite and ægirine, nepheline also occurring in places. The relations of the three main centers exterior to these lines, those of the Euganean and Berici Hills and Monte Vulture, are uncertain and need not be discussed here.

Aug. 1, 1899.

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[*] Rosenbusch, Mikr. Phys., ii, 1896, p. 614.

[†] We cannot determine this point in regard to the other rocks of San Pietro, as Eigel (Min. Petr. Mitth., viii, p. 73, 1886) unfortunately did not determine the alkalies separately.

[‡] Doelter, Abh. Akad. Wiss. Wien., xxxviii, p. 41, 1878.

ART. XXXII.—*Mineralogical Notes: Melonite* (?), *Coloradoite*, *Petzite*, *Hessite*; by W. F. HILLEBRAND.

IN a suite of tellurides from the Mother Lode region in California, collected by Mr F. L. Ransome, of the Geological Survey, I have been able to identify a nickel telluride (melonite?), a mercury telluride (coloradoite?), besides petzite and hessite.

Melonite?

Several specimens from the old Stanislaus mine,* the original source of Genth's melonite† (Ni_2Te_3?), but now included with the Melones and other claims under the name Melones mine, showed plainly a nickel telluride of reddish white cast of color like that of bismuth,‡ thickly scattered in grains and showing pronounced cleavage and a brilliant luster. A concentrate was prepared by the aid of cadmium-boro-tungstate solution, and this was then laboriously hand-picked by the aid of a powerful glass. There was certainly more than one foreign mineral present, but identification was not possible with exception of a little gold and petzite. The chief impurity was a silver mineral, presumably hessite. If so, the analyses seem to indicate also native tellurium. A perfectly pure article could not be extracted because of difficulty in sometimes distinguishing the foreign minerals from the one sought, but it was hoped that an analysis of both the selected and rejected portions would permit of calculating the composition of the nickel mineral with considerable certainty on the reasonable assumption that no impurity had been removed in relative excess over the other or others.

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* Mr. Ransome has kindly furnished the following notes:

"This mine is situated on the south slope of Carson Hill, Calaveras Co., just above Robinson's Ferry, and has not been worked for several years. There is no prominent vein at this point, the ore being very irregularly distributed, and occurring in small nearly horizontal stringers in dark clay slates of Carboniferous age with nearly vertical dip. This mine has long been known as a source of interesting tellurides, and Dana, in the sixth edition of his System of Mineralogy, cites petzite, calaverite, melonite, and altaite as occurring here. The other ore minerals are pyrite and galena, the latter in small quantities. The ore-bearing stringers are filled with quartz, or a mixture of quartz and calcite as a gangue. The rich masses of tellurides appear, however, to be usually associated with calcite (or dolomite). The melonite of specimen No. 16 shows at least one perfect cleavage, resembling in the thinness of the resulting laminæ the cleavage of the micas. The cleavage faces are usually somewhat curved, and possess a splendent metallic luster. (The cleavage can best be detected by carefully scraping thin folia from such a brilliant surface with a sharp knife point.) The color of the cleavage faces is pale bronze-yellow."

† Long *o* accented.

‡ Under a lense and to the unaided eye in certain lights the color appears more bronze-yellow.

The analyses below represent the composition of (*a*) the rejected, (*b*) the original, and (*c*) the selected material. Analysis (*b*) is given chiefly because of the cobalt determination, the nickel being probably a little high. Although but 0·22 and 0·13 grams respectively were available for the analyses (*a*) and (*c*), the data are believed to be more trustworthy on the whole than those of (*b*), hence the figures under (*d*) have been obtained by calculation based on (*c*) and (*a*) only, after reducing them to 100. Under (*e*) is shown the theoretical composition of $NiTe_2$. Small amounts of iron, traces of copper, and perhaps of one or two other elements are omitted, besides the ¾–2 per cent of gold and petzite that remained unattacked by cold dilute nitric acid in which the nickel mineral is readily soluble.

The specific gravity of (*b*) at 22·5 was 7·72, which is probably higher than the true density of the pure nickel telluride.

	a	*b*	*c*	*d*	*e*
					$NiTe_2$
Te........	75·29	77·72	80·75	81·40	81·29
Ni......	15·71	17·16	18·31	18·60	18·71
Co		·10			
Ag.......	8·44	5·09	·86		
	99·44	100·07	99·92	100·00	100·00

If hessite and native tellurium constitute the foreign admixture, the mineralogical composition of (*a*) and (*c*) is shown to be as follows:

	a	*c*
$NiTe_2$	84·44	97·89
Hessite	13·51	1·38
Tellurium	2·05	·73
	100·00	100·00

There is here indicated a considerable selective separation of the foreign minerals, since the relative proportions of tellurium and hessite are very different in the two mixtures, but the amounts operated on were so small that a very slight actual error in a determination might give rise to this change in the relative proportions of impurities without affecting materially the ratios found for the components of the nickel telluride. The three analyses taken together point unmistakably to $NiTe_2$ as the formula for the latter mineral. The question then arises, is this Genth's melonite, or is it a new mineral? Genth found

Te	73·43
Ni	20·98
Ag	4·08
Pb	·72
	99·21

from which, after deducting hessite, altaite, and free tellurium, he deduces the formula Ni_2Te_3, requiring Te 76·49 and Ni 23·51.

The difference between this and my own analyses is too great to admit of bringing them into accordance, yet I am indisposed to believe that two minerals are represented, for both occurrence and appearance are opposed to such a view. The present mineral is from the same source as Genth's, its physical characteristics, so far as ascertainable, coincide with those of melonite, and it is called melonite by the people at the mine. Melonite was considered by Genth to be hexagonal on the strength of its eminent cleavage and the observation of a single microscopic six-sided plate. Mineralogically a hexagonal form in the pyrite group, assuming this mineral to belong there, is not to be looked for, but the evidence in favor of hexagonal crystallization is too meager to permit this to be used as an argument one way or another.

Coloradoite?

One small specimen from the Norwegian mine showed in dolomite, petzite, hessite, and a mercury telluride. Superficially the latter was not to be distinguished from the accompanying petzite and hessite, and it was in insufficient amount to admit of analysis for the determination of its formula. It, however, gave the tests noted by Genth for the original coloradoite from Colorado, and in addition the following characteristic may be noted. On heating with strong nitric acid it becomes coated with a white insoluble salt of mercury, which retards further action of the acid.

It is in all probability coloradoite, and if so this is its second known locality of occurrence, though I have been informed that a mercury telluride has recently been found in Western Australia.

Petzite.

One specimen of petzite from the Norwegian mine gave such an abundance of pure material that an analysis seemed desirable.

The results were as follows:

		Ratios.	
Au	25·16	1·98	1·00
Ag	41·87		3·04
Te	33·21	1·00	
Se	trace		
Mo	·08		
	100·32		

Approximate specific gravity at 23° C. 8·925. The molybdenum may exist as sulphide. The ratios lead almost exactly to the formula $Au_2Te, 3Ag_2Te$.

Hessite.

In conclusion may be given an analysis of hessite from a new locality, San Sebastian, Jalisco, Mexico, the material being received from Mr. Frederic Chisolm.

Specific gravity at 26° C. 8·24

Ag	61·16	
Te	36·11	
Pb	1·90	
S, Fe, Zn	·83	(difference)
	100·00	

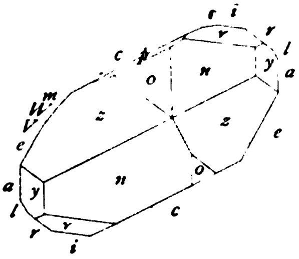
Laboratory of the U. S. Geological Survey, June, 1899.

ART. XXXIII.—*Note on Epidote and Garnet from Idaho;* by CHAS. PALACHE.

IN the fall of 1898 Messrs. C. L. Whittle and Wm. Beals, Jr., presented to the Harvard Mineralogical Museum a suite of mineral specimens collected by them in the Seven Devils Mining District, Idaho, chiefly from the Peacock and White Monument mines. The ore of these mines is argentiferous chalcocite and bornite; these specimens, however, show but little ore material, being composed almost wholly of the associated vein minerals, among which were determined: (1) from the Peacock Mine—epidote, almandite garnet, quartz, chrysocolla, malachite, brochantite, hematite, and chlorite; (2) from the White Monument Mine—calcite, malachite, melaconite, grossularite garnet, and epidote; (3) from the Copper Key Mine—andradite garnet.

The Peacock Mine was the source of the powellite first described by Melville;* the specimens were therefore carefully searched for that mineral but none was found.

1



2

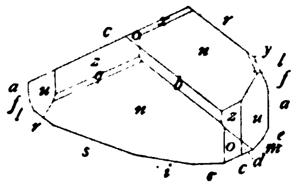


FIG. 1. *c*(001), *a*(100), m(102), W(305), V(405). *e*(101), σ($\bar{1}03$), *i*($\bar{1}02$), *r*($\bar{1}01$), *l*($\bar{2}01$), *z*(110), *o*(011), *p*(016), *n*($\bar{1}11$), *y*($\bar{2}11$), η($\bar{2}12$).

FIG. 2. *c*(001), *a*(100), *b*(010), *e*(101), m(102), *f*($\bar{3}01$), *l*($\bar{2}01$), *r*($\bar{1}01$), *s*($\bar{2}03$), *i*($\bar{1}02$), σ($\bar{1}03$), *z*(110), *u*(210), *o*(011), *n*($\bar{1}11$), *x*($\bar{1}12$). *d*(111), *q*($\bar{2}21$).

Epidote.—Epidote is the most abundant and most interesting mineral present. It is in well developed crystals lining the walls of cavities in massive epidote. The crystals are dark green in color and often of large size, the largest collected being two inches in length and breadth. Mr. Whittle saw a cavity in which a large number of perfect crystals upwards of a foot in length had been destroyed by the miner's pick.

The crystals have the normal epidote habit, prismatic parallel to $\bar{b}$, and are generally flattened parallel to the basal plane so that lense-shaped cross-sections are common; they are invariably implanted on an end of the orthoaxis, $\bar{b}$. The majority of the crystals are terminated simply by *n* ($\bar{1}11$), sometimes together with *b* (010), and in the orthodome zone show *c* (001), *i* ($\bar{1}02$), *r* ($\bar{1}01$), and *a* (100). A few crystals, however, showed a much richer series of forms as seen in figs. 1 and 2, which are orthographic projections on the clinopinacoid and reproduce the distortion of the crystals.

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* W. H. Melville, this Journal, xli, 1891, page 138.

Twinning was observed on several crystals according to the usual law: twin plane *a* (100). In one crystal the twinning was repeated, two narrow lamellæ intervening between the two principal individuals.

Many of the crystals exhibit a strong tendency to scale off in concentric shells parallel to all the crystal faces. This was particularly noticeable in the crystals figured above, even the smallest faces preserving their luster and permitting good measurements after the surface layers had been removed. The shelly structure sometimes gives rise to a brilliant iridescence on the faces of the crystal and is generally associated with a bleaching of the color, presumably due to surface alteration.

Some of the epidote crystals are imbedded in quartz of later growth, the latest deposit in the cavities. A single specimen from the Decorah Mine showed such imbedded crystals of a pale green epidote which were exceptional in being doubly terminated.

The epidote is in places largely changed to a scaly chloritic material which was not further examined.

Garnet.—The garnet from the Peacock Mine is almandite, probably the same as that analyzed by Melville[*] from the same locality. It is in light to dark brown, completely developed, and very symmetrical crystals showing the forms *d* (101), *p* (211), and sometimes *s* (321). They are imbedded in glassy copper-stained quartz from which they easily separate, leaving beautifully sharp casts.

A second type of garnet is found in the Peacock Mine specimens. Rough crystals an inch or less in diameter show a pronounced dodecahedral form, the edges slightly truncated by the icositetrahedron (211). The centers of the crystals are of a dark brown garnet substance; but the exterior is uniformly coated with a shell of clear quartz $\frac{1}{2}^{mm}$ in thickness conforming in minutest detail to the form of the garnet crystal. A thin section through such a crystal showed that the quartz in one of these shells formed but a single crystal, and it appears to represent an original crystallization controlled in the disposition of its material by the garnet crystal. Outside of the quartz is in many instances a similar coating of light green iridescent epidote and here and there thin plates of hematite are arranged between the layers of quartz and epidote. Calcite has also formed similar layers in some crystals and where afterwards removed by solvents leaves the crystals cavernous. The surfaces of the garnet crystals, whether coated with quartz or epidote, are smooth and plain and the effect on looking at an unbroken crystal is as of pseudomorphs of these two minerals after the garnet.

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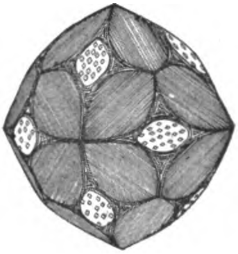
[*] Loc. cit., p. 138.

In specimens from the White Monument Mine, crystals of cinnamon-brown grossularite garnet showing only the form *p*(211) are associated with a little epidote in an impure limestone. In these garnets layers of crystalline calcite are interpolated as in the last described crystals, with the difference that here the outer layer is of garnet substance.

Crystals of brown andradite garnet from the Copper Key Mine are notable for the etching which they have undergone. The forms originally present were *d*(101) and *p*(211) in almost equal development and perfectly symmetrical. But as shown in fig. 3, the crystals have been much rounded by deep corrosion of all the edges, the solvent action having been greatest at the ends of the trigonal axes where uneven facets have been produced. Shallow rounded grooves replace the edges between *d* and *p* and a rounding of the angles at the ends of the axes gives in some cases an approximation to a cube face. The etch facets would give no measurable reflections but their position shows that they are in part trisoctahedrons and in part hexoctahedrons. The faces of both *d* and *p* still retain a brilliant luster, but the former are marked by beautifully sharp and symmetrical etch pits of rhombohedral outline, their edges parallel to the dodecahedral edges of the crystal; and the faces of *p* are grooved quite deeply parallel to the same edges.

3



A large specimen of vein material from the White Monument Mine consists of large cleavage rhombohedrons of calcite, each of which serves as a core to a spherical layer of radial fibrous calcite. The curved outer surface of these layers is a drusy one formed by sharp calcite rhombohedrons, which in its turn is coated over with a thin layer of quartz crystals. The interspaces between the spheroidal masses are filled with a mixture of dead black melaconite and green chrysocolla with a small amount of malachite.

Chrysocolla and malachite occur throughout the specimens as coatings on epidote or other crystals and in tiny veinlets which penetrate all the interstices of the other vein minerals.

Brochantite was found in several specimens in slender transparent emerald-green prisms or in radial-fibrous aggregates interspersed among the epidote crystals.

Hematite has been already mentioned as forming thin plates parallel to faces of the larger garnets; similar plates are found in the massive epidote and in quartzose portions of the vein.

Mineralogical Laboratory, Harvard University.

Art. XXXIV.—*On Thermoelectricity in Certain Metals;* by LUDWIG HOLBORN and ARTHUR L. DAY.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany. Laid before the Königlich Preussische Akademie der Wissenschaften, Berlin, July 20, 1899.]

In connection with the investigation of the gas thermometer at high temperatures and the application of thermo-elements of the platinum metals to the comparison of its results, the need of a law which should accurately express the relation between the electromotive force developed by the latter and the temperature became strongly felt. Theoretical considerations led us to carry the research further, and include the lowest available temperatures as well; thus the range of the investigation became so broad that the behavior of thermo-elements was shown in a much clearer light than heretofore, as will be seen from the following brief sketch of the results.

Avenarius, as is well known, was the first to show that the electromotive force of a thermo-element, expressed as a function of the temperature, approximated very closely to a parabola, and this result has been confirmed for various temperature ranges by Tait, Knott and MacGregor, and Noll. Up to the present time, however, the agreement can be said to be satisfactory only between 0° and 300–400°, and even here several metals show considerable irregularities. Attempts have even been made recently to apply logarithmic formulæ where the difference in temperature between the junctions was large.

The thermo-elements which we have investigated have not, to be sure, followed the law of Avenarius in every case over the entire measured temperature domain, but within very wide limits the agreement is so astonishingly exact that the failure of the law to apply further can only be regarded as an evidence of some change in the condition of the metal investigated at that point—perhaps due to the absorption of gases. The great range of temperature to be covered by this investigation made it only possible to include metals which remain chemically unchanged at high temperatures, i. e., the platinum group together with gold and silver. Thanks to the kind assistance of the firm of Heräus in Hanau and the chemical laboratory of the Reichsanstalt, especially Prof. Mylius, we were able to lay much emphasis upon the chemical purity of the metals investigated.

One of the best means of testing the purity of a metal is often the measurement of its electrical resistance. This has been done in this case; in fact one of the metals—gold*—offers a remarkable example of the effect of slight impurities upon the temperature coefficient of the resistance.

In connection with the pure metals several alloys were also investigated but offered no exception to the application of the law.

The metals, with the exception of iridium and rhodium, were in the form of drawn wires of 0·6^{mm} diameter; these two were rolled out into narrow rectangular strips slightly larger than the wires. Wires as well as strips were brought to a bright glow electrically before being used and their homogeneity tested by connecting their ends with a galvanometer while lying in the electric oven, the temperature being maintained first at 500°, then at 1000°. Only the two gold wires Au_0 and Au_1 showed any considerable effect, an electromotive force amounting to 60 microvolts being here obtained. The palladium wires behaved somewhat peculiarly, showing an electromotive force of about 150 microvolts when first laid in the oven at 1000° and half as much at 500°; this decreased in a short time to less than a third of the original value. There is an evident connection between this and a phenomenon conspicuous when the wires were first heated as above mentioned; they did not glow uniformly at once, but several sharply defined dark stretches were noticeable which slowly diminished in length and disappeared after some ten minutes, the wire then glowing quite uniformly.

The electric oven consisted of several concentric tubes of clay separated by air spaces, the innermost tube carrying a coil of nickel wire which could be freely heated to 1300°.

The elements were heated in a porcelain tube which extended through the oven without being in contact with it except on the outside where the cold projecting ends were supported. The hot junction lay in the middle of the oven, and the wires, carefully insulated from each other, were carried out at the ends to the cold junctions (0°).

For the temperature measurement a platinum—platin-rhodium thermo-element was used which had been compared with the gas thermometer between 0° and 1000°. Assuming that one junction is maintained at 0° while the other is heated to t°, it is possible to express the electromotive force of the element between 300° and 1000° as a quadratic function of t within the limits of the errors of observation. Above 1000° the temperatures were obtained by extrapolation of this function.

With this standard element the other elements were severally compared, the four wires being melted together at the hot junction and the electromotive force of any particular metal then being measured with respect to the pure platinum which with the platin-rhodium formed the standard element and indicated the temperature of the hot junction.

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* This gold wire (Au_0 of the table) had already shown surprising behavior in its electrical and thermal conductivity—Jaeger and Diesselhorst, Sitz. Ber. Berl. Akad., 1899, p. 719.

The temperature was held as nearly constant as possible at intervals of about 50° and the electromotive force of the metals in various combinations measured; the values for the exact intervals contained in the table being obtained from these by graphical interpolation.

The table contains first the coefficients a*, $100\,b$, and $10000\,c$ of the formula

$$e = -a + bt + ct^2$$

the thermoelectric potential difference (e) being expressed in microvolts; second, the temperature limits t_1 and t_2, within which the formula has been found to apply; third, the mean temperature coefficient a of the electrical resistance between 0° and 100°; and finally, the differences (calculated – observed) expressed in degrees between the values obtained from the formula and the corresponding observed values of the electromotive force. Where the formula no longer applies the differences are enclosed in parentheses.

It will be seen that with the exception of palladium, the Avenarius formula applies between a definite comparatively low temperature and the highest temperature observed, the difference between observed and calculated values being in the mean less than 1°, smaller, in fact, than the differences observable in the same element under different experimental conditions. In the case of palladium, however, two distinct equations are distinguishable, the one for the lower temperatures (below 400°) and the other for the higher (above 600°), and between the two lies a domain of 200° where neither equation applies. Otherwise the agreement between observed and calculated values is nearly as good as with the other elements except in the case of the alloy 90 Pd, 10 Pt, where at the lower temperatures the sensitiveness is very small. This element in particular is also the only one having a minimum within the temperature domain of these observations, the change in direction falling within the limits where neither of the equations applies.

Regarding the difference between the value of the constants a, b and c for various specimens of the same material, no very useful conclusions can be drawn from the material at hand. In the case of gold the value of a seems to decrease with

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* It is evident that when the formula contains a constant term, it cannot apply downwards as far as 0°. If, as is nearly always the case, this constant is negative (for which reason it appears with the negative sign in the formula), it indicates that the curve is too steep to pass through 0°.

	Au$_0$–Pt	Au$_1$–Pt	Au$_2$–Pt	Ag–Pt	Rh$_1$–Pt	Rh$_2$–Pt	Ir–Pt	90 Pt, 10 Ru –Pt	
a	644	398	388	0	169	228	84	367	**a**
$10^2 \times$ **b**	684·9	876·9	892·0	589·1	700·0	734·4	670·0	922·9	**b** $\times 10^2$
$10^4 \times$ **c**	96·8	84·4	83·4	132·0	68·0	66·8	60·0	15·6	**c** $\times 10^4$
t$_1$	300°	300°	300°	0°	200°	250°	100°	300°	t$_1$
t$_2$	950°	1050°	1050°	950°	1250°	1300°	1200°	1300°	t$_2$
a	0·00214	0·00389	0·00397	0·00405	0·00440	0·00446	0·00394	—	*a*
0°	—	—	—	0·0°	(−24°)	(−31°)	(−12·5°)	(−40°)	0°
50	(−56°)	(−28°)	(−29°)	−1·9	(−12)	(−17)	(− 5·8)	(−25)	50
100	(−30)	(−15)	(−15)	+0·4	(− 6·3)	(− 8·2)	− 1·1	(−17)	100
150	(−15)	(−11)	(− 8·6)	−0·7	(− 2·4)	(− 5·6)	0·0	(− 9·6)	150
200	(− 5·5)	(− 7·0)	(− 4·8)	−1·8	− 0·3	(− 3·2)	+ 0·9	(− 5·0)	200
250	(− 1·8)	(− 3·2)	(− 2·1)	−1·5	+ 0·2	− 1·5	0·0	(− 2·4)	250
300	0·0	− 0·1	+ 0·4	+0·2	+ 1·0	+ 0·1	0·0	0·0	300
350	+ 0·2	− 0·1	+ 0·3	+0·1	+ 0·5	+ 0·4	− 0·2	0·0	350
400	+ 0·3	− 0·1	+ 1·1	+0·4	+ 0·6	+ 1·0	+ 1·2	+ 0·4	400
450	− 0·6	− 0·8	+ 0·1	+0·2	+ 0·5	+ 0·6	0·0	0·0	450
500	− 0·2	− 1·2	+ 0·8	−0·1	+ 0·8	+ 0·6	0·0	− 0·3	500
550	+ 0·2	− 0·1	+ 0·1	+1·0	+ 0·3	+ 0·5	+ 0·2	+ 0·5	550
600	− 0·6	− 0·4	− 0·5	+1·9	+ 0·1	+ 0·5	− 0·1	− 0·2	600
650	− 0·9	+ 1·4	+ 2·0	+1·5	− 0·1	+ 0·1	0·0	+ 0·3	650
700	− 0·7	0·0	0·0	+0·1	− 0·3	+ 0·1	− 0·7	+ 0·3	700
750	− 0·5	− 0·6	− 0·5	+0·1	+ 0·2	+ 0·2	+ 0·1	+ 0·5	750
800	− 0·7	− 1·0	− 1·0	−1·1	− 0·7	− 0·6	− 0·2	0·0	800
850	0·0	− 0·5	− 1·0	−0·9	− 0·1	− 0·6	− 0·6	+ 0·3	850
900	+ 1·1	− 0.2	− 0·3	−0·2	− 0·7	− 1·0	+ 0·1	+ 0·2	900
950	+ 1·7	+ 0·7	0·0	+0·8	− 1·2	− 1·0	+ 0·4	− 0·5	950
1000		+ 1·3	+ 0·1		+ 0·3	− 0·1	+ 0·4	− 0·3	1000
1050		+ 0·4	− 0·4		+ 1·5	+ 0·6	+ 1·0	− 0·1	1050
1100					+ 1·3	+ 0·4	+ 1·0	− 0·3	1100
1150					+ 1·1	+ 0·7	+ 1·6	− 0·4	1150
1200					+ 0·7	+ 0·8	+ 1·7	− 0·9	1200
1250					+ 1·1	+ 1·3		+ 0·2	1250
1300						+ 1·0		− 0·8	1300
Mean	±0·74	±0·74	±0·77	±1·02	±0·76	±0·75	±0·75	±0·40	Mean

	90 Pt, 10 Pd–Pt		10 Pt, 90 Pd–Pt		$Pt-Pd_1$		$Pt-Pd_2$		
a	0	330	0	−596	0	0	0	0	a
$10^2 \times$ b	216·0	447·6	−211·0	−572·0	499.3	316·2	525·3	340·2	b $\times 10^2$
$10^4 \times$ c	44·0	1·6	28·0	82·0	44·0	80·8	44·0	82·4	c $\times 10^4$
t_1	0°	300°	0°	600°	0°	600°	0°	600°	t_1
t_2	300°	1200°	350°	1200°	350°	1250°	350°	1300°	t_2
a	—	—	—	—	0·00373	0·00373	0·00377	0·00377	a
0°	0·0°		0·0°		0·0°		0·0°		0°
50	+ 2·8		0·0		− 3·1		+ 0·4		50
100	+ 1·9		− 5·8		− 0·5		− 0·2		100
150	− 1·4	(−18°)	0·0		− 1·9		− 1·1		150
200	− 2·6	(−10)	+ 4·0		+ 0·2		− 0·4		200
250	− 0·7	(− 4·1)	+18·3		+ 1·6		− 0·5		250
300	+ 3·2	− 0·6	+17·1		+ 2·1		+ 0·8		300
350	(+ 7·8)	+ 0·4	0·0		+ 0·4		− 0·2		350
400	(− 1·8)	+ 1·7		(−24°)	− 0·3	(−15°)	− 0·5	(−13°)	400
450	(−24)	+ 0·4		(−17)	(− 4·5)	(−11)	(− 4·5)	(− 8·9)	450
500	(−36)	+ 0·4		(−12)	(− 8·9)	(− 7·0)	(−10)	(− 5·8)	500
550	(−49)	+ 0·6		(− 4·8)	(−15)	(− 3·0)	(−16)	(− 2·7)	550
600		− 0·2		0·0	(−19)	− 1·6	(−27)	− 1·1	600
650		+ 0·2		0·0		+ 0·1		+ 0·1	650
700		− 0·2		0·0		+ 0·5		+ 0·9	700
750		− 0·6		0·0		+ 1·8		+ 1·5	750
800		− 0·2		−0·5		+ 0·8		+ 0·8	800
850		− 0·8		−0·2		+ 0·1		+ 1·0	850
900		0·0		−0·4		+ 0·5		+ 0·2	900
950		0·0		−0·3		+ 1·1		0·0	950
1000		− 0·4		+1·1		+ 0·9		− 0·7	1000
1050		+ 0·8		+0·6		+ 0·7		− 0·9	1050
1100		+ 0·6		−0·3		− 0·8		− 1·4	1100
1150		+ 0·6		+0·1		− 1·5		− 1·0	1150
1200		+ 0·2		+0·7		− 1·2		− 1·1	1200
1250						− 0.4		− 0·1	1250
1300								+ 0·4	1300
Mean	±2·27	±0·61	(±9·8)	±0·47	±1·61	±1·04	±0·59	±0·91	Mean

increasing purity of the metal, the gold Au_0, according to the chemical analysis, containing 0·09 per cent iron and 0·08 per cent copper, while the two other specimens were very pure.

In order to obtain some idea of the behavior of the thermoelements below 0°, preliminary observations were made at −80° and −185°, from which it was found that all the elementary metals with the exception of palladium have a minimum in the vicinity of −100°. The difference between observed and calculated values increase as the temperature is diminished, in the case of palladium, however, the value calculated from the first equation agrees very well with the observed electromotive force at −100°.

The observed electromotive force of the several metals in microvolts at the two temperatures mentioned follows, the arrangement being the same as in the large table. For purposes of comparison the values obtained experimentally at 450° and 950° are added.

	950°	450°	−80°	−185°
Au_1	15532	5270	−307	−130
Au_2	15612	5314	−315	−166
Ag	17484	5320	−302	−160
Rh_2	12798	4422	−312	−235
Ir	11688	4146	−320	−283
90 Pt, 10 Ru	9814	4102	−388	−534
90 Pt, 10 Pd	4068	1714	− 87	−106
10 Pt, 90 Pd	2566	−290	+146	+240
Pd_2	10670	3296	−392	−774

The platinum wire of the standard element to which all the others were referred, was further compared with another wire (a = 0·00388) from the same source prepared with especial care. This latter, as also the wire Pd_2, upon analysis by Prof. Mylius, showed no impurities amounting to 0·1 per cent. The electromotive force of these two platinum wires referred to the same platin-rhodium wire showed a difference of 1° at a temperature of 1000°, while a third wire of pure platinum from another firm differed 12° at the same temperature. The last had, however, a smaller temperature coefficient (a = ·00376) and was in all probability less pure.

SCIENTIFIC INTELLIGENCE.

I. BOTANY.

1. *Note on Cycadofilices;* by G. R. WIELAND (communicated).—This group of ancient plants is held to comprise the genera *Nœggerathia*, *Medullosa*, *Cladoxylon*, *Lyginodendron*, *Heterangium*, and *Protopitys*, with the Medullosan allies *Colpoxylon* and *Steloxylon*. In addition *Myeloxylon*, *Alethopteris* and *Neuropteris* are now recognized as appendicular leaf structures. Most palæobotanists regard the group as intermediate in structure between Ferns and Cycads. The literature concerning it is much enriched by the recent paper of Dr. Scott: *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.* III. *On Medullosa anglica, a new representative of the Cycadofilices;* by D. H. Scott, F.R.S. (Philosoph. Trans. of the Royal Society of London, 1899). As in the treatment of *Lyginodendron* and *Heterangium* this valuable contribution is accompanied by a full series of photographs illustrating structure. *Medullosa anglica* (from the Lower Coal Measures of Britain) is shown from the study of specimens representing all vegetative organs but the fructification to be the most Fern-like of the *Cycadofilices*. Dr. Scott's discussion of its relationships is very interesting. I quote from his conclusion: "The evidence is gradually accumulating which connects the Cycads (and by a less direct line the other gymnosperms also) with the Ferns. The fossil evidence, very strong by itself, is supported by the morphology of the reproductive organs, and by the great discovery of the multiciliate spermatozoids which we owe to Ikeno and Hirase and to Webber. We thus see that external resemblance is not always fallacious; the Fern-like foliage of *Stangeria*, the 'Maiden hair tree,' pointed in the right direction long before botanists were able to follow the clue."

2. *The Hepaticæ and Anthocerates of California;* by MARSHALL AVERY HOWE. Memoirs Torrey Botanical Club, vol. vii, pp. 208, 8^{c}, pl. 88–122. Issued Aug. 5, 1899.—This monograph is the most thorough presentation of the hepatics of any portion of the United States which has yet been published. The main portion embraces a detailed account of the genera and species found in California, with full and exact descriptions of the species supplemented by copious, critical notes on synonymy, distribution, etc., together with keys to the genera and species. In the introduction the author enumerates the different collectors of hepatics of the west coast with notes on their collections, and gives tables showing the comparative distribution of Californian species in the northeastern United States, British Isles, northern and central Europe and northern Asia. The Californian species number 86 as compared with 150 of the Eastern States, a relatively large number when one considers the smaller area covered

by the present treatise and the fact that some portions of California, especially the higher mountains, have not yet been thoroughly explored. While, on the one hand, the small rainfall of the lower districts is unfavorable to the development of a rich bryophytic vegetation, the greater height of the mountains as compared with those of the Eastern States is favorable to such development. Two facts are brought out by the table, viz., the number of species peculiar to the Pacific is proportionally greater than of those peculiar to the region of Gray's Manual, and the hepatic flora of California has more in common with Europe than with the eastern and central United States. The author has not only brought together what was previously known as to the structure and nomenclature of California hepatics, but he has also contributed a large amount of original observations in his descriptions and the accompanying notes, and the large number of illustrations add greatly to the value of this excellent monograph.

W. G. F.

3. *Californian Hypogæous Fungi;* by H. W. HARKNESS. Proc. California Acad. Sci., 3d Series, vol. i, No. 8, pp. 241–292, pl. xlii–xlv. Issued July 8, 1899.—Our knowledge of the hypogæous fungi of the United States has hitherto been very imperfect. Beyond occasional references in mycological writings and in the special papers by W. R. Gerard, we are indebted mainly to the previous papers of Dr. Harkness for what we know about our native species. The present monograph is the first extended treatise on the subject and is destined to become a classic in North American mycology. We are now able for the first time to recognize that, contrary to the general opinion, the hypogæous forms are represented by a large number of species in this country. The detection of hypogæous fungi is very difficult because in nearly all cases they exhibit above ground no evidence of their existence. Long experience and great patience are necessary to discover them and the collections of Dr. Harkness represent the labor of many years. The district examined specially by him extended from the northern State line of California to the Tehachappi range on the south and from the valley of Donner Lake on the east to the Pacific coast. The best locality for most species was found to be the foot hills at an elevation of about 1500 feet and the most productive season was early spring. Rodents it appears are very fond of the mature fungi, and they are especially destructive to forms which grow under Sequoias.

The number of species described is 105 besides three species, *Sphæria Setchellii* Harkness, *S. Zobelii* Tul., and *Sporophaga cyanea,* the type of a new genus, which are parasitic on different Tuberaceæ. Of the 25 genera included in this monograph Leucophleps, Myrmecocystis, Piersonia and Terfeziopsis are new to science. The new species number 56, of which 8 belong to the genus Tuber, 7 to Hymenogaster and 5 to Octaviania and Leucophleps. For a detailed account the reader must be referred to descriptions and notes of Dr. Harkness given in his monograph, which is illustrated by four folded plates, of which the drawings, in part colored, were made by Dr. Eisen. With regard to the economic value of the Californian Hypogæa Dr. Harkness states that he has found none of the edible varieties of Europe, although *Tuber Californica* is nearly identical with an edible species of Italy. All of the Californian species are edible, but they are so rare that their use is practically out of the question. Notes are however given concerning a species found at Marysville, belonging probably to the genus Terfezia, which grows in large quantities and is esteemed a delicacy. W. G. F.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—The forty-eighth meeting of the American Association was held at Columbus, Ohio, during the week from August 19th to 26th. The President of the meeting was President Edward Orton of Columbus. The number of members in attendance was not conspicuously large—the total registration being three hundred and fifty-two—but much interest was manifested throughout and the meeting proved as a whole highly successful; the various local committees did all in their power to contribute to this end.

The retiring President, Professor F. W. Putnam, delivered an address on Monday, August 21, upon the subject "A Problem in American Anthropology." Other able addresses were also given by the Vice Presidents of the several sections.* Another feature of the meeting was a public lecture with lantern illustrations by Professor C. E. Munroe on the application of modern explosions. Wednesday, August 23d, was devoted by the botanists to the honor of the famous bryologists, William S. Sullivant and Leo Lesquereux, both of whom had their homes in Columbus. A number of excursions were carried out, one of the most interesting being to the Gas Fields.

The place selected for the meeting of 1900 is New York City and the date set is the last week in June, a radical change which will meet with universal approval. The meeting of 1901 will be held in Denver, Colorado.

The officers nominated for 1900 are as follows :

President: R. S. Woodward, Columbia University.

Vice Presidents: Section A, Asaph Hall, Jr., University of Michigan ; Section B, Ernest Merritt, Cornell University ; Section C, James Lewis Howe, Washington and Lee University ; Section D, J. A. Brashear of Pittsburg ; Section E, J. F. Kemp, Columbia University ; Section F, C. B. Davenport, Harvard University ; Section G, W. Trelease, Missouri Botanical Garden ; Section H, A. W. Butler of Indianapolis ; Section I, C. M. Woodward of Washington University.

Permanent Secretary, L. O. Howard of Washington. General Secretary, Charles Baskerville, University of North Carolina. Treasurer, R. S. Woodward, Columbia University.

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* These are printed in full in the issues of Science, commencing with August 25.

The following is a list of papers accepted for reading at the recent meeting:

SECTION A. *Mathematics and Astronomy.*

G. B. **HALSTED**: Report on progress in non-Euclidean Geometry.

L. E. **DICKSON**: Report on progress in the theory of linear groups.

CLEVELAND ABBE: Recent progress in theoretical Meteorology.

ASAPH HALL, JR.: The aberration constant from observations of Polaris.

R. W. **MCFARLAND**: Ancient eclipses and chronology.

H. C. **LORD**: Some points in the design of a spectroscope.

JOS. V. **COLLINS**: Note on Grassmann's proof that there can be but two kinds of lineal multiplication of two factors.

G. J. **STOKES**: The theory of mathematical inference.

J. R. **EASTMAN**: Recent progress in positional Astronomy.

R. A. **FESSENDEN**: The determination of the nature of Electricity and Magnetism, including a determination of the density of the ether.

G. A. **MILLER**: On the commutators of a group.

S. **KIMURA**: Linear vector functions.

J. **WOODBRIDGE DAVIS**: Internal forces that generate stellar atmospheres.

T. H. **SAFFORD**: Practical astronomy during the first half of the present century.

SECTION B. *Physics.*

F. C. **CALDWELL**: Apparatus for the demonstration of the varying currents in the different conductors of a rotary converter.

H. T. **EDDY**: A new graphical method of constructing the entropy-temperature diagram from the indicator card of a gas or an oil engine.

WILLIAM HALLOCK: Compound harmonic vibration of a string.

LYMAN J. **BRIGGS**: A new form of electrical condenser having a capacity capable of continuous adjustment.

J. MCK. **CATTELL**: Time of perception as a measure of the intensity of light. Relations of time and space in vision.

CHARLES K. **WEAD**: The musical scales of the Arabs. Medieval organ pipes and their bearing on the history of the scale.

H. S. **CARHART** and K. E. **GUTHE**: An absolute determination of the E. M. F. of a Clark cell.

AUGUSTUS TROWBRIDGE: Quantitative investigation of the coherer.

K. E. **GUTHE** and M. D. **ATKINS**: Polarization and polarization-capacity.

R. A. **FESSENDEN**: Current and voltage curves in the magnetically blown arc and in the aluminum electrolytic cell. Some new apparatus—tachometer, chronograph, data collector, induction coil, balance for standardizing amperemeters, standard of induction. Measurement of magnetism in iron and the relation between permeability and hysteresis. Location of smokeless discharge by means of colored screens. Note on the age of the earth.

B. E. **MOORE**: Polarization and internal resistance of the copper voltameter.

C. A. **SKINNER**: Concerning the fall of potential at the anode in a Geissler tube.

F. A. **WOLFF**, JR.: The equipment and facilities of the Office of U. S. Standard Weights and Measures for the verification of electrical standard and measuring apparatus. An experimental test of the accuracy of Ohm's law.

O. L. **FASSIG**: March Weather in the United States, etc.

D. B. **BRACE**: A new spectrophotometer and a method of optically calibrating the slit. On achromatic polarization in crystalline combinations.

E. V. **CAPPS**: Optical calibration of the slit of a spectrometer.

E. J. **RENDTORFF**: On differential dispersion in double refracting media.

FRED E. **KESTER**: A method for the study of phosphoresent sulphides.

B. V. **HILL**: Accidental double refraction in colloids and crystalloids.

C. E. **MENDENHALL**: A bolometric study of the radiation of a black body between 600° and 1100° C.

F. A. Saunders: A bolometric study of the radiation of an absolute black body.

F. E. Nipher: On thermodynamic surfaces of P. V. T. for solid, liquid and gaseous state.

S. R. Cook: On the escape of gases from the planets according to the Kinetic Theory. On flutings in Kundt's tube.

J. S. Stevens: Relation of magnetisation to the modulus of elasticity.

Thos. Gray: The dielectric strength of oils. Some unexpected errors in wattmeter measurements.

David P. Todd: Note on the preparation of reticles.

E. W. Scripture: The nature of spoken vowels, with reference to the theories of Helmholtz and Hermann. Electrical anesthesia.

J. F. Mohler: Pressure and wave-length.

A. Wilmer Duff: The attenuation of sound and the constant of radiation of air.

Section C. *Chemistry.*

Wilder D. Bancroft: The relation of physical Chemistry to technical Chemistry.

Wm. McPherson: On the constitution of oxy-azo-compounds.

W. R. Whitney: The nature of the change from violet to green in solutions of chromium salts.

J. J. Kessler, Jr.: Micro-structure of antimony-tin alloys.

Louis Kahlenberg: The electrolytic deposition of metals from non-aqueous solutions.

A. A. Noyes: Some experimental illustrations of the electrolytic dissociation theory.

Rudolf DeRoode: Methods of analysis of sulphite solutions used in paper making.

C. G. Hopkins: Improvement in the chemical composition of the corn kernel.

H. W. Wiley and W. H. Krug: Some new products of maize stalks (with illustrative experiments).

E. F. Ladd: Soil humus.

J. T. Willard: The relation of fertilizers to soil moistures.

Thos. Clark: Secondary heplytamine.

Wm. B. Sholer: Propane trisulphonic acid.

H. C. Biddle: On the derivatives of isnoctive of formhydroxamic acid, and their relation to fulminic acid.

Jas. H. Stebbins, Jr.: The Reichert figure of butter.

Geo. W. Sargent: The determination of nickel in nickel steel. The quantitative estimation of boric acid in tourmaline.

W. A. Noyes and J. W. Shepherd: Camphoric acid, alpha-hydroxy-dihydro-cis-campholytic acid, and the synthesis of dimethyl-cyan-carbon-ethyl-cycle-pentanone.

M. Gomberg: Diazo-caffeine. The preparation of the tri-phenyl-chlor-methane and tri-phenyl-carbinol.

F. J. Pond: The action of sodium methylate upon the dibromides of pro-penyl compounds and unsaturated ketones.

C. C. Howard: Some secondary cyclic amines.

Wm. McPherson and Robert Fischer: On naphalene-azo-alpha-naphthol and its derivatives.

W. A. Noyes: Esterification experiments with hexa- and tetrahydroxylic acids.

Charles Baskerville: On the condensation of chloral with ortho-, meta- and para-nitranilines. Note on the occurrence of chromium, titanium and vanadium in peats. On the universal distribution of titanium.

T. W. Richards: The atomic weight of calcium.

M. E. Hiltner: Preliminary report on a new method for the determination of carbon dioxide.

A. H. Gill: Analysis of oils.

A. S. Mitchell: Examination of lemon flavoring extracts.

F. W. Woll: The composition of American and foreign dairy salt.

H. A. Weber: Notes on testing soils for application of commercial fertilizers.

A. P. Saunders: A determination of the transformation point of sodium sulphate.

F. P. Dunnington: Notes on the estimation of total carbon in iron and steel.

H. M. Fernberger and **E. F. Smith**: Electrolysis of metallic phosphate solutions.

F. J. Pond, O. P. Maxwell and **G. M. Norman**: The action of sodium methylate upon the dibromides of propenyl compounds and unsaturated ketones.

R. K. Meade and **J. C. Atkins**: On the determination of volatile combustible matter in coke and anthracite coal.

Edgar F. Smith: Observations upon tungsten.

W. L. Hardin: The atomic mass of tungsten. Derivatives and atomic mass of palladium.

M. J. Moore: Notes on the determination of sulphur in pig iron.

Joseph H. James: An electrolytic study of benzoin and benzil.

J. K. Haywood: Some boiling-point curves.

Lily G. Kollack: Electrolytic determinations and separations.

J. G. Shengle and **E. F. Smith**: The precipitation of copper by zinc.

R. W. Tunnell and **E. F. Smith**: Action of hydrochloric acid gas upon sulphates. selenates, tellurates and phosphates.

C. H. Clarke and **E. F. Smith**: The electrolytic oxidation of succinic acid.

A. R. Foster and **E. F. Smith**: The persulphates of rubidium, cæsium and thallium.

C. A. Browne, Jr.: The chemical composition of butter fat The chemistry of rancidity in butter fat.

Paul Murrill: Halides and perhalides of the picolines.

SECTION D. *Mechanical Science and Engineering.*

W. T. Magruder: Supports of beams in tests of transverse strength. Crystallization in bronze test pieces. The fracture of spheres.

Thomas Gray: The illustration of critical speeds of shafts. The friction of balls in thrust bearings. The fuel value of cereals.

F. C. Wagner: A novel method of testing a locomotive boiler.

Wm. S. Aldrich: Electric mining of bituminous coal. Some engineering experiences with Spanish wrecks.

W. K. Palmer: A new exact graphical method for designing cone pulleys.

J. W. Shepherd: Some experiments on combustion in locomotive boilers.

C. B. Morrison: Some thermal determinations in heating and ventilating buildings.

A. G. Fried: Defective vision of school children.

SECTION E. *Geology.**

Edward Orton: The geology of Columbus and vicinity.

Frank Leverett: Glacial phenomena of Central Ohio.

Warren Upham: Glacial and modified drift in Minneapolis, Minn.

G. Frederick Wright: Lateral erosion at the mouth of Niagara Gorge.

C. H. Hitchcock: The geology of Oahu. Hawaiian Islands.

C. D. Walcott: A Pre-Cambrian Upper Algonkian terrane.

W. H. Hobbs and **C. K. Leith**: The petrographic province of Fox River Valley, Wisconsin.

A. F. Foerste: Age and development of the Cincinnati anticline.

Charles Schuchert: The Lower Devonian aspect of the Lower Helderberg and Oriskany formations.

H. S. Williams: The Silurian-Devonian boundary in North America.

J. J. Stevenson: The section at Schoharie, N. Y.

Joseph Le Conte: The Ozarkian and its significance in theoretic Geology.

George H. Ashley: The geological results of the Indiana Coal Survey.

J. A Holmes: The Cape Fear section in the coastal plain.

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* Including papers presented before the Geological Society of America.

E. T. **Dumble**: Triassic coal and coke of Sonora, Mexico.

J. H. **Pratt**: The occurrences of corundum.

J. A. **Holmes**: Some geological conditions favoring water-power developments in the South Atlantic region.

John M. Clarke: *Paropsonema;* a peculiar Echinoderm from the Intumescens Fauna, New York. Remarkable occurrence of Orthoceros in the Oneonta Sandstones of New York. The Squaw Island "Water Biscuit," Canandaigua Lake, New York.

Mary A. Fleming: The pot holes of Foster's Flats (now called Niagara Glen) on the Niagara River.

W. **Simonds**: A consideration of the interpretation of unusual events in geological records.

W. J. **McGee**: The Pre-Lafayette (Tennessean) base level.

Chas. E. **Slocum**: The relative ages of the Maumee glacial lake and the Niagara Gorge.

F. B. **Taylor**: The Galt moraine and associated drainage.

E. H. **Barbour** and W. C. **Knight**: Discovery of new invertebrates in the Dinosaur beds of Wyoming.

E. H. **Barbour**: The rapid decline of geyser activity.

SECTION F. *Zoology.*

C. C. **Nutting**: On the utility of phosphorescence in deep sea animals.

B. B. **Myers**: The course of the fibres in the optic chiasma of the common American toad, *Bufo lentiginosus.*

Henry B. **Ward**: On *Reighardia*, a new genus of Linguatulida.

Carl H. **Eigenmann**: Cave animals: their character, origin, and their evidence for or against the transmission of acquired characters.

F. M. **Webster**: Have we more than a single species of Blissus in North America?

M. **Burton Williamson**: Æstivation of *Epiphragmorphora traskii* (Newcomb) in S. California.

R. W. **Schufeldt**: Natural taxonomy of the class Aves.

Susanna P. **Gage**: Notes on the morphology of the chick's brain.

Simon H. **Gage**: Further Notes on the Brook Lamprey (*Lampetra wilderi*). Respiration in tadpoles of the toad (*Bufo lentiginosus*). Photographing Natural History specimens under water or other liquids with a vertical camera.

H. C. **Oberholse**: Geographical variations illustrated by the horned larks of North America.

W. G. **Johnson**: Effects of hydrocyanic acid gas upon animal life and its common use.

C. L. **Marlatt**: A discussion of *Aspidiotus cydoniæ* and its allies.

B. F. **Kingsbury**: The histogenesis of muscle in the metamorphosis of the toad. (*Bufo lentig. Americanus*)

Theo. Gill: The progenitors of Batrachians.

Herbert Osborn: Observations on the variation, life-history and habits of a minute locust (*Edipoda maritma Uhl* (?)).

A. D. **Hopkins**: A chart for illustrating the origin and evolution of animal and vegetable life.

SECTION G. *Botany.**

F. L. **Stevens**: The fertilization of *Albugo bliti.*

Francis Ramaley: The embryo sac of *Leucocrinum montanum.*

A. S. **Hitchcock**: Notes on subterranean organs.

W. J. **Beal**: Some monstrosities in spikelets of Eragostis and Setaria with their meaning.

C. E. **Bessey**: Studies of vegetation of the high Nebraska plains. One thousand miles for a fern. Are the trees advancing or retreating upon the Nebraska plains?

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* Including also (below) titles of papers presented before the Botanical Club.

WM. SAUNDERS: The breeding of apples for the Northwest plains. Useful trees and shrubs for the Northwest plains of Canada.

BYRON D. HALSTED: Field experiments with "Nitragin" and other germ fertilizers.

A. J. GROUT: Suggestions for a more satisfactory classification of the Pleurocarpous mosses.

BRUCE FINK: Notes concerning the study of lichen distribution in the Mississippi Valley.

W. C. STEVENS: Botanical teaching in the secondary schools.

IDA CLENDENIN: Botanical teaching in the secondary schools.

H. L. BOLLEY: The duration of bacterial existence under trial environments.

H. A. HARDING: The occurrence of the black rot of cabbage in Europe.

W. T. SWINGLE: A summary of our knowledge of the fig.

WM. TRELEASE: The classification of Botanical publications.

E. B. COPELAND: The geotropism of the Hypocotyl of Cucurbits.

A. F. WOODS: The destruction of chlorophyll by oxidizing enzymes.

C. O. TOWNSEND: The effect of hydrocyanic acid gas upon the germination of seeds.

W. G. JOHNSON: Some physiological effects of hydrocyanic acid gas upon plants.

W. B. STEWART: Etiolative reactions of *Sarracenia* and *Oxalis*.

JULIA B. CLIFFORD: The mycorhiza of *Tipularia*.

J. C. ARTHUR: The cultures of *Uredineae* in 1899.

F. E. LLOYD: The embryology of *Vaillantia hispida*.

J. H. SCHAFFNER: Division of the megaspore of *Erythronium*.

IRWIN F. SMITH: The fungous infestations of agricultural soils in the United States.

H. L. BOLLEY and L R. WALDRON: The occurrence of calcium oxalate and lignin during the differentiation of the buds of *Prunus Americana*.

HERMANN VON SCHRENK: Two diseases of *Juniperus*.

HENRY KRAENER: The crystals in *Datura stramonium L*

L. M. UNDERWOOD: What shall we regard as generic types? Summary of our knowledge of the distribution of Fungi in America.

L. C. CORBETT: A device for registering plant growth.

A. D. SELBY: The tamarack swamp in Ohio. The introduced species of Lactuca in Ohio. On *Plasmopara Cubensis*. The flora of Franklin Co, Ohio.

O. F. COOK: Notes on some of the work of the Division of Botany of the U. S. Department of Agriculture.

T. A. WILLIAMS: Some features of the investigations on grasses and forage plants, in charge of the Division of Agristology, U. S. Department of Agriculture.

J. W. T. DUVEL: A brief embryological study of *Lactuca scariola* L.

A. S. HITCHCOCK: Distribution of some Kansas plants. Some wheat crosses.

W. R. LAZENBY: Unusual development of leaves and growth of plants from cuttings.

A. D. HOPKINS: Some botanical notes by an entomologist.

C. E. BESSEY: A greasewood compass plant. A visit to the original station of the Rydberg cottonwood. The wilting of *Cleome integrifolia*. The powdery mildew of *Polygonium aviculare*.

N. L. BRITTON: Report on Mr. Heller's Botanical Exploration of Porto Rico. Notes on the northern species of Celtis. Remarks on some species of Quercus.

F. S. EARLE: Tomato fruit rot.

W. J. BEAL: Botanical Club of the Michigan Agricultural College. The introduction of *Cabomba Caroliniana* in Michigan.

W. SAUNDERS: The Arboretum and Botanic Garden of the Central Experiment Farms, Ottawa, Canada.

F. E. LLOYD: Two hitherto confused species of Lycopodium.

W. A. KELLERMAN: Ohio sections for Lea's oak. Labels for living plants

SECTION H. *Anthropology.*

W. J. McGee: The beginnings of Mathematics.

J. McK. Cattell: The scientific societies and institutions of the United States. New anthropometric methods. Report of committee on White Race in America.

In Memoriam—Dr. Daniel G. Brinton.

E. W. Scripture: Researches in experimental phonetics, with demonstration of results. Inadequacy of the present tests for color-blindness, with demonstrations of a new test. Observations on after-images and cerebral light. Observations on the economy of sleep.

C. E. Slocum: Regarding the evidences of ancient prehistoric man in the Maumee River Basin.

G. Frederick Wright: The latest discoveries of traces of glacial man at Trenton, N. J., and the light thrown upon them by a comparative study of the gravels of the Delaware and Susquehanna Valleys.

Thos. Wilson: Recollections of M. Bourcher de Perthes.

W. A. Phillips: The aboriginal quarries and shops at Mill Creek, Miami Co., Ill.

Charles K. Wead: The national diatonic scale: a chapter of musical history.

Robert Steiner: Allan Stevenson's trance. Prehistoric settlement, Big Kiokee Creek, Columbia Co., Ga.

Frank Russell: A comparative study of the physical structure of the Labrador Eskimos and the New England Indians, illustrated by lantern slides.

James Mooney: The Cherokee River cult.

George G. McCurdy: Extent of instruction in Anthropology in Europe and America.

Eliza T. Houk: Evolution.

SECTION I. *Social and Economic Science.*

John Hyde: Natural distribution as modified by modern agriculture.

Cora A. Benneson: Federal guarantees for maintaining Republican governments in the States.

Henry Farquhar: Calculations of populations in June, 1890.

Florence Kelley: Power of the consumer economically considered.

M. A. Clancy: The basis of war and peace.

Mansfield Merriman: The increase in the median age of the population of the United States since 1850

Washington Gladden: Moral tendencies of existing social conditions.

R. A. Fessenden: Hysteresis in social, economic and vital phenomena.

John S. Clark: Science and art in social development.

Laura Osborne Talbott: The personal equation as a psychological factor.

Daniel Folkmar: Positive science and methods in education.

T. M. Balliet: Some new aspects of educational thought.

C. M. Woodward: The manual element in education.

H. T. Newcomb: The spoils system in theory and practice. Trusts: A study in industrial evolution.

OBITUARY.

Professor **Robert Wilhelm Bunsen**, the veteran German chemist, died in Heidelberg on the 16th of August last at the age of eighty-eight. Of what he accomplished for science during his long period of active service, only brought to a close by the infirmities of great age, chemists and physicists hardly need to be informed—with the founding of the department of spectrum analysis and the development of the methods of gas analysis, his name will be ever as surely connected as it is in popular use with the "Bunsen burner." But to those who enjoyed the privilege of working under him, of learning to know personally as well as to come into somewhat close contact with his keen mind, his death comes as a direct personal loss. This is so well expressed by a gifted chemist* in a recent number of Nature that no apology is needed for quoting his words here: . . . "But this experimental work, great and important as it is, is not the greatest or most important work that he accomplished. It is as a teacher and as an example that the name of Bunsen is and will be chiefly honored and remembered. It is only those who have had the benefit of working under and with him who can fully understand the feelings of affection and respect with which they regard his memory. To those who had the privilege of his intimacy, of whom I can happily claim to be one, his friendship will remain as an abiding source of gratification. As an investigator he was great, as a teacher he was greater, as a man and a friend he was greatest."

Sir Edward Frankland, the distinguished English chemist, died on the 9th of August in his seventy-fifth year. A recent writer says of him, his "title to fame rests securely upon his important experimental investigations in pure chemistry, accomplished chiefly within the twenty years from 1848 to 1868, and upon the impetus which was given to theoretical chemistry by the promulgation of his views concerning the combining capacity, or valency as it is now called, of the elements, which he derived from the results of his experimental work."

Dr. Daniel Garrison Brinton of Philadelphia, the distinguished and learned anthropologist, died on July 31st in his sixty-third year. He held for many years the Professorship of American Archæology and Linguistics in the University of Pennsylvania. His contributions to science, particularly in the line of the languages of the original tribes of North America, were numerous and of great value.

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* Sir Henry E. Roscoe in Nature for August 31. The same writer gave an admirable account of Bunsen's life and work some eighteen years since in vol. xxiii of Nature's Series of Science Worthies.

THE

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[FOURTH SERIES.]

ART. XL.—*Types of March Weather in the United States. The relations existing between mean atmospheric pressure, the prevailing character of the weather, and the paths of storms;* by OLIVER LANARD FASSIG. With Plates VI and VII.

Introduction.—It has long been recognized that the field of view of a national weather service is too small to study to the best advantage the daily weather phenomena as they pass over any one country.

In the past twenty years, several researches of great importance have appeared in which the field of investigation comprised large portions of the northern hemisphere, some of them indeed including both hemispheres. The results of these investigations show that the weather of a certain locality is intimately associated with atmospheric conditions very far removed from the immediate locality under consideration. For example, Hoffmeyer and Teisserenc de Bort have shown that certain conditions of pressure over the North Atlantic Ocean have a direct bearing upon the weather of Central Europe. Blandford and Eliot have demonstrated that certain marked phases of Indian weather find their explanation in pressure conditions in Central Asia and over the Indian Ocean. There are a few well-defined and persistent areas of high and low pressure of great extent in both hemispheres which control very largely the weather conditions of the globe. Recent researches tend to show that some of the attention heretofore given to transient cyclonic areas might well be diverted to the study of the so-called *permanent* high areas. The extensive areas of high pressure found upon any chart showing the mean monthly pressure conditions over the globe are real forces in controlling the weather over wide areas. Any marked displacement of these areas from their normal or average position, or any unusual variation in the intensity of their gradients, is associated with unusual conditions of wind direction, temperature, and rainfall in their vicinity. The daily weather chart has made us all familiar with the kind of weather associated with the transient areas of high and low pressure which pass across the country every few days: with the clear skies and light, variable winds of a high area, the rainy unsettled weather near the center of low pressure. In interpreting the average weather conditions associated with the large persistent areas of average high or low pressure we find that the same rules apply as in the case of the transient areas based on synchronous observations.

In view of the slow movements of these areas of high and low pressure, their vastly greater extent and greater persistence, we have, for purposes of weather forecasting, an evident advantage over the method of following up the quickly moving cyclones and anti-cyclones of smaller extent, which may enable us to foresee the general character of the weather, for longer periods than we are now able to do.

A better knowledge of the movements of these "great centers of action," as M. Teisserenc de Bort calls them, would undoubtedly prove a valuable supplement to present methods in the practical work of forecasting. For example, should further investigation show that, when the pressure in the North Atlantic high area is above its normal value, and extends farther inland than usual, the paths of all storms, including the West Indian hurricanes which may arise during this time, are moved westward of their usual paths, we shall be able to determine much more accurately the probable paths of our storms.

In any event, since no material improvement has been made in late years in either the accuracy or the period of weather forecasts, it behooves us to give every encouragement to any suggestion which gives reasonable promise of advance, especially in the direction of forecasts for a longer period.

In the following pages a brief synopsis of the more important researches referred to above is presented in order to give a clearer conception of their nature and claims. I have attempted to follow a similar method of investigation in a detailed study of March weather conditions in the United States, with special reference to the Middle Atlantic States. An effort is here made to show that the weather east of the Rocky Mountains is largely controlled during March in its general characteristics by the relative development and the relative positions of the persistent areas of high pressure over the Atlantic Ocean and over Manitoba in British North

America. The study of conditions during March brings to light several interesting facts about the controlling factors in the weather east of the Rocky Mountains. An average pressure above the normal in the area of persistent high pressure over the Atlantic Ocean invariably brings to the Atlantic States mild ocean temperatures; an average pressure above the normal of the persistent high area over the interior of British North America as invariably brings to the Central and Atlantic States the cold air of the northwest. During a normal month of March the Atlantic States are alternately under the control of the high area in the northwest and that over the Atlantic Ocean, resulting in the changeable weather and strong contrasts in temperature so characteristic of March.

An intimate relation is also shown to exist between these pressure areas and the distribution and amount of rainfall, and in the paths of storms across the country.

Historical review.—Hoffmeyer, the eminent Director of the Danish Meteorological Service, as early as 1878 recognized the importance of securing observations over the widest field possible in the discussion of weather sequences.* It is to his efforts that the world is indebted for initiating in 1873 the excellent series of daily synoptic weather charts of the North Atlantic Ocean and Western Europe. He showed to what a great extent the winter conditions of Northern Europe are dependent upon the prevailing pressure distribution over the North Atlantic Ocean. He made a careful study of the origins and paths of storms over the Atlantic Ocean,† and pointed out how it would be practicable by joining Iceland, Greenland, the Azores and Bermuda, with neighboring mainlands by cable, to secure a daily weather chart sufficiently comprehensive to permit of making fairly accurate forecasts of the approach of storms, and to note carefully the pressure changes in the area of persistent high pressure in the neighborhood of the Azores.

The winter of 1879–80 was very severe throughout Central Europe; M. Léon Teisserenc de Bort,‡ of the Central Meteorological Bureau of France, made a careful study of the conditions which prevailed, and of the causes which produced them. In charting the mean monthly pressure over the North Atlantic and over Europe for the months of December, January and February, it was revealed that during December the area of high pressure, usually over the Azores, throughout the year, was during this month over France and neighboring regions; during a portion of January the area had resumed its normal position; again during February it was found over France. The normal distribution of pressure during the winter months gives to France a mild-climate with prevailing southwesterly winds. During the presence over France of the area of high pressure, however, in December and February some of the lowest temperatures experienced during the present century occurred; the prevailing winds were northerly and much of the precipitation was in the form of snow and not in the usual form of rain. Further study of mean pressure conditions over the globe for a long series of years led M. Teisserenc de Bort to define and classify the different maximum and minimum areas of pressure which the atmosphere presents at the surface of the earth. These areas, which have a certain permanence in a given season and which are found on all charts of mean pressure, he designates "great centers of action of the atmosphere." Their existence is related to the position of the great centers of action of the globe, regions which either by their physical properties or by their orographic features initiate the great centers of atmospheric action, so-called because they govern the circulation of the winds all round them. These centers of action vary considerably from year to year, during the same month, in position and in extent. Their motion is not a regularly progressive movement in the well-defined direction made familiar to us in the study of the transient highs and lows of our daily weather map, but is irregular, a shifting from place to place—now to the north or south, then to the east or west, of an average position—following no law at present recognizable. It was shown that the character of a season is well defined when it is known what types of isobars prevail. Two important principles have been formulated by M. Teisserenc de Bort as a result of these studies:

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* Distribution de la pression atmosphérique pendant l'hiver sur 'l'Ocean Atlantique Septentrional et influence que en resulte sur le climat de Europe. In Cong. intern. mét., Paris, 1878; also in Met. Zeitschr., Wien, 1878, pp. 337–347, 5 pls.

† Étude sur les tempêtes de l'Atlantique Septentrional. 4°. Copenhague, 1880. 47 pp. 4 pls.; also in Met. Zeitschr., Wien, 1880, pp. 345–361.

‡ Étude sur l'hiver de 1879–80. Annal. du Bureau Centr. Mét., Paris, vol. iv, 1881.

1. When a region of a certain extent shows an excess of temperature either absolute or relative to the temperature of other points in the same latitude, there is a tendency to the formation of a minimum in that region, and an almost exact coincidence between the barometric minimum and the maximum of temperature; moreover there is a certain proportionality between them. This tendency is shown either by the existence of a closed minimum, or by an inflection of the isobars.

2. Areas of maximum pressure have a tendency to form in the neighborhood of regions where the temperature is low, either absolutely or relatively to their latitude.

The general circulation of the atmosphere due simply to difference in temperature between the equator and the poles, would produce a belt of high pressure around the globe near latitude 30° N. The differences of temperature which are produced over the globe between neighboring regions, and especially between continents and seas in the same latitude, by changing the density of the lower strata of the atmosphere, destroy the regularity of the isobars (as observed in the southern hemisphere) and bring about the formation of closed areas of high or low pressure which break up the zones, as shown in the northern hemisphere. (See Plate VI.)

In these researches of M. Teisserenc de Bort we have the first indications of a method which may lead to long-range forecasts. Van Bebber* suggests that the barometric maxima owe their origin and life mostly to the upper air currents; so that the air masses which are carried up in certain regions, even in the high latitudes and in the lower atmosphere, go to build up the highs. The usual explanation, he maintains, that the barometric maxima are fed by passing depressions, does not suffice, and leads to many contradictions.

General Greely maintains† that "a study of the annual barometric fluctuations will reveal their intimate connection with the prevalent types of weather or climate, so that abnormal departures in certain regions will be recognized as dominating factors in producing, later in the season, abnormal weather conditions in other and quite distant sections of the world." That "annual atmospheric waves, with their crests and troughs, move over the northern hemisphere somewhat in the same manner as the waves of high pressure, known as cold waves, move throughout the winter months from the interior to the Atlantic seaboard."

Mr. Eliot,‡ the Meteorological Reporter to the Government of India, seems to have established:

1. That there are well-marked pressure oscillations of long period over the Indian area.
2. That they are directly related to the largest and most important features of the weather in India, viz: the character and distribution of the precipitation of rain and snow in the Indian monsoon area.
3. That they are also directly related to the great atmospheric movements over India.

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* J. van Bebber, Typische Witterungserscheinungen. Archiv der deutschen Seewarte, v. 1882. 4°. Hamburg, 1882.

† International pressure and storm charts. Report of Chief Signal Officer for 1891. Washington, 1891, page 750

‡ J. Eliot, A preliminary discussion of certain oscillatory changes of pressure of long period and short period in India. Indian Met'l. Mem., vol. vi, part ii, Calcutta, 1895, page 117.

Hildebrandsson* finds that the barometric variations about the Azores and about Iceland are nearly always opposed. That the same is true of the variations in Siberia and Alaska. That there exists a sort of oscillation in the pressure of the air between a center of action of high pressure and another neighboring one of low pressure. In comparing, on the other hand, the curves for the Azores and for Siberia, he finds a remarkable agreement. The variations at Key West do not accord with those in the Azores, but are in accord with those at San Diego. The departures of the same sign nearly always cover very large areas.

According to Major Rawson,† the so-called permanent areas of high pressure in the northern hemisphere do not have a steady progressive movement, but shift to one side or another about a fairly well-defined average position.

Poincaré‡ has in recent years presented to the French Academy of Sciences many communications upon the probable cause of these anomalous pressure changes, attributing them to the influence of the moon.

Thus we see that there is abundant testimony to establish the existence of well-defined larger movements of the atmosphere, which differ in extent and character of movement from the transient high and low areas pictured upon our daily weather maps; also that these movements have a direct and important bearing upon local climate. Leaving the historical side of the question, we come to the consideration of the positions occupied by these persistent areas of high and low pressure during March, and their influence upon local climates in the United States.

Average weather conditions during March.—In a study of weather conditions it is essential to bear in mind the "law of winds" announced independently over fifty years ago by our own countryman William Ferrel, and by Buys-Ballot of Holland: where there is a difference of pressure between neighboring regions on the same level the air will flow out of the region of high pressure into the region of low pressure. Owing to the revolution of the earth about its axis the flow of air will not be along straight lines, but along lines constantly bending to the right of the initial direction in the northern hemisphere; to the left in the southern hemisphere. The daily weather chart issued by the United States Weather Bureau has made us familiar with such systems of wind circulation as they pass across the country every few days, and has enabled us to see why the winds at any given place change rapidly in direction as an area of low or high pressure passes over the place. It is also essential to bear in mind certain relations existing between temperature and moisture conditions of the atmosphere. At a given temperature the maximum amount of invisible moisture in a given space is a fixed quantity. Should the temperature be lowered, some of the moisture will assume a visible form such as cloud or rain. Conversely, if the temperature be raised the space will become dryer as the capacity for moisture is increased by raising the temperature. Hence a portion of atmosphere rising from the surface of the earth will become relatively more moist as it rises, owing to the decrease in temperature upward from the surface. As the atmosphere contains at all times more or less moisture, a rising current will produce clouds and eventually rain, while a descending atmosphere becomes relatively dryer as it descends.

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* Quelques recherches sur les centres d'action de l'atmosphère. Stockholm, 1897.

† Anticyclonic systems and their movements, Quart. Journ. Met. Soc., London, vol. xxiv, 1898.

‡ See Compt. Rend., Acad. Sci., Paris, 1889 et seq.

Now let us apply these simple laws to conditions in areas of low and high pressure. In a low pressure area we have seen that the atmosphere flows in toward the center from all directions, consequently at or near the center of the area it must rise and be lowered in temperature; the moisture of the atmosphere will approach saturation; clouds will be formed and if it continue to rise rain will follow. Hence an area of low pressure is apt to be characterized by cloudy and rainy weather. The atmosphere in a region of high pressure descends; hence it grows warmer as it descends. As it grows warmer, it becomes dryer; any clouds which may have existed over this area tend to become dissolved. Hence an area of high pressure is an area of clearing or clear weather. We shall see later that these principles hold good for average pressure conditions as well as for the transient conditions shown on our daily weather maps. That is to say, if in a certain region we find the mean pressure for the month to be considerably higher than in neighboring regions, the weather there will be found to be generally fair; while in a region where the pressure has been relatively low the prevailing weather will be found to be cloudy and unsettled. We can now see that if we can definitely locate areas of mean high pressure and mean low pressure, during a specified time, we shall have a means of determining readily the prevailing direction of the winds, this, in turn, enabling us to determine roughly the temperature and the rainfall.

Throughout this discussion I have considered the isobar of 30·1 inches as defining roughly the outer limit of a high area, and the isobar of 29·9 inches as enclosing the area of low pressure.

This division into high and low areas has been uniformly maintained for convenience. These limits were adopted as the mean atmospheric pressure at sea level is approximately 30·0 inches; any area above 30·1 inches is consequently safely above normal, while any area below 29·9 inches is safely below normal.

The characteristic features of pressure distribution during March in the northern hemisphere are as follows: a large area of excessively high pressure (see Plate VI) prevails over Asia. In the western hemisphere there are three well-defined areas of high pressure: one over British North America, another extending across the North Atlantic at about the latitude of thirty degrees, from the Azores westward, the third in the Pacific Ocean between California and the Hawaiian Islands. This triple arrangement of the areas of high pressure about the United States during March plays a most important part in determining the character of the weather. The areas of low pressure in the extreme northern portion of the Atlantic and Pacific Oceans are well developed and clearly defined.

March is proverbially a windy month, with strong contrasts and rapid changes in temperature. It is a transitional month, during which there is a breaking up of winter conditions and a beginning of summer conditions. The Middle Atlantic States (see Plate VI) lie between the normal March isotherms of 25° and 45°, though the mean temperature varies greatly from year to year. At Baltimore, where the normal March temperature is 42°, the values have varied from 35° to 49° during the past thirty years. The rainfall east of the Rocky Mountains attains a maximum of from five inches to seven inches in the eastern Gulf States and diminishes steadily to the west and north to about one inch over the Rocky Mountain plateau. Storms are frequent, and their paths across the country evenly distributed from the Lake region to the Gulf (see fig. 1, p. 335).

March, 1898.—See Plate VII. The month of March, 1898, was excessively warm in Maryland and Delaware; at Baltimore the daily excess of temperature was over seven degrees. There was but one short period of frost and this was free from injurious effects upon crops in these States. There were but few high winds and none of them destructive. The month was balmy and almost devoid of the usual stormy March winds. The rainfall, while somewhat below the normal, was sufficient to supply all the needs of growing crops. Crop correspondents of the United States Weather Bureau in Maryland and Delaware reported vegetation at the close of the month from three to four weeks in advance of the average season.

In looking for an explanation for the unusually warm spell of weather, it is found necessary to go far beyond the limits of these States. Reference to the Climate and Crop Report of the Weather Bureau for this month showed that the temperature was above the normal in all sections of the country east of the 100th meridian, the largest excess being in southern Canada, where it reached twelve degrees. West of the 100th meridian the temperature was everywhere below the normal, in Montana the departure being minus nine degrees. According to the United States Monthly Weather Review, the pressure was above normal from the Mississippi River eastward to the Atlantic coast, also on the northern slope and the north Pacific coast. It was below normal over California, the southwest, the Rocky Mountain regions south of Idaho and the plains from the Gulf of Mexico to the British possessions. The pressure was unusually high for the season over New England and the Canadian maritime provinces. The areas of high pressure of the month in most cases followed the northern track and persisted for several days over New England. The low areas in the majority of cases moved from the southwest to the lake region, then easterly north of New England. As a result the prevailing winds were southerly, giving fair weather and abnormally high temperatures to all of New England. The dividing line between southerly winds on the one hand, and northwesterly winds on the other extended northeasterly from Denver to Duluth, a position considerably farther to the northwest than usual. The winds of the Pacific coast were almost invariably from the northwest, while those of the mountain and plateau region were generally southwesterly. The rainfall was below the normal in the Atlantic coast and east Gulf States, and also in all the Pacific coast States; it was abundant in the Ohio and Mississippi Valleys.

In order to get a more comprehensive view of the situation, the pressure conditions prevailing over the entire continent, so far as observations could be gathered, were charted. Observations of mean atmospheric pressure were, at the same time, charted for the entire northern hemisphere so far as material was available, in order to study the situation in its broadest relations. The result is shown on Plate VII.

Looking at the pressure conditions over the North American continent and the neighboring oceans, and bearing in mind the principles referred to in the preceding paragraphs relating to wind and weather conditions in high areas and low areas of pressure, the abnormal weather conditions during March find a ready explanation.

The area of high pressure over the Atlantic which usually extends from the Azores westward to Florida (see Plate VI) was, during March, 1898, materially modified in form and extent: it was found to be divided into two segments with the western segment unusually developed and enlarged. Over the entire eastern section of the United States and Canada the weather was under the control of a high area of exceptional strength for the season and the place, which brought to these regions either light variable winds or southerly winds. During the entire month ocean conditions prevailed, that is, the temperatures were equable in the main, and the regions were mostly free from the usual incursions of the cold continental weather conditions from the northwest. The low temperatures of the North Pacific coast find a similar explanation in the position and development of the high area in the north Pacific. The normal position of the Pacific Ocean high area brings to the North Pacific coast a mild, southwesterly wind. During March, 1898, this high area was found farther to the north and at the same time having greater energy than usual, thus bringing a colder northwesterly wind to these regions.

A glance at the chart will show that the high area over British North America was about normally developed and exerted no abnormal influence upon the temperature of the neighboring regions.

An abnormal distribution of pressure is also shown over the eastern North Atlantic and over Central Europe. Let us examine the records to see whether this departure in pressure distribution was accompanied by abnormal weather conditions in accordance with this distribution of pressure. Again examining Plate VI and bearing in mind the law of winds, we see that the prevailing winds over central and eastern Europe are from the southwest, bringing with them mild ocean temperatures and frequent rains.

During March, 1898 (see Plate VII) a segment of the Atlantic high area was found considerably to the north of its usual position, while a trough of low pressure existed over Central Europe. This distribution of pressure gives to the coast regions and to England northerly winds with low temperatures and precipitation in the form of snow. To Central Europe it brings southeasterly winds with rains, the direction of the wind being largely controlled by the excessively developed Siberian high area. Quoting from the Weekly Weather Review of the London Meteorological Office, we find that "with the exception of a few mild days about the middle of the month the weather of March was generally cold and changeable with frequent showers of snow or sleet. . . . Until the concluding week very few depressions of importance were observed in the immediate neighborhood of our islands, the centers of the large Atlantic disturbances keeping as a rule well away to the northward. Winds varied considerably but were mainly from the west in Scotland and from the north or northeast in England and Ireland."

Crossing the channel into France, we find that the weather was generally cold, being 3° below the normal at Paris. The dominant winds were from the northeast with prolonged rains. Snows were more frequent than rains in the northwest and the north of Europe, according to the monthly bulletin of the French Meteorological Bureau. From "Das Wetter" for March, 1898, we learn that the weather of central Europe was of a kind generally associated with low areas; cloudiness was far above the average, the rainfall was generally above the normal. Temperatures varied, being above in some sections and below in others, on the whole not deviating far from the normal.

In a method similar to that just described, pressure conditions were charted for the month of March for all years from 1877 to 1899; where observations were available, isobars were drawn for the entire northern hemisphere, but the investigation of weather conditions was confined to the United States, with special reference to the Middle Atlantic States. Having drawn the isobars, the departures from normal temperature and rainfall were entered upon the same chart. The months were then classified according to the departures from the normal temperature, in order to learn what relations existed between the distribution of pressure and the temperature departures.

The mean temperature of March was found to be decidedly above the normal during the years 1878, 1882, 1894, and 1898 in the Middle Atlantic States.

Warm Marches: March, 1878.—The temperature was excessively high in all portions of the United States and Canada, with a maximum departure of +20° over Manitoba; from this center the departures gradually diminished to 4° or 5° on the Atlantic and Gulf coasts and to 3° or 4° on the Pacific coast. The striking feature about the pressure distribution was the total absence of the high area usually over British North America, at least up to 60° north latitude. In the central portion of the United States, where the pressure usually averages about 30·0 inches, it was below 29·9 inches, causing a well-developed barometric depression. This distribution of pressure caused prevailing winds to blow into the central portion of the country from the Atlantic Ocean, the Gulf, and from the Pacific Ocean. The Atlantic high area, while only normally developed in its western extension, practically controlled the wind directions and temperatures over a great extent owing to the absence of the British high. The precipitation was deficient east of the Mississippi River and south of the Lakes.

March, 1882, fig. 3.—During this month the temperatures were from 2° to 4° above normal in nearly all sections east of the Mississippi River; to the west and northwest they were from 4° to 8° above. The pressure distribution was totally different from that of March, 1878, but the eastern half of the country was again plainly under the influence of the Atlantic high area; this was not only unusually strong but extended inland far beyond the average limits. All the characteristics of high area weather prevailed in the eastern and southern states during the month; high temperatures, light winds, and comparatively dry weather. The northern high area was well developed but the center was farther to the north and east than usual, and not in a position to throw detached masses of cold air into the United States. Without observations to fix the position of the Pacific high, it is difficult to discuss intelligently the control of weather on the Pacific coast.

March, 1894.—The temperatures ranged from normal along the 105° meridian to 9° above in the Lake regions and to 3° below westward to the Pacific coast, again showing a decided control of the country east of the Mississippi by the Atlantic high area. The rainfall was deficient almost throughout the area enclosed by the isobar of 30·1 inches.

It is clearly apparent from a study of the foregoing analysis that in each case the eastern half of the country was under the domination of an extension of the Atlantic area of high pressure, which gave to this region either prevailing southerly or easterly winds from a warmer region, or prevailing light, variable winds. It will also be noted that when a region is clearly within this high area, generally within the isobar of 30·1 inches, there is a deficiency of rain, even when easterly winds are indicated by the arrangement of the isobars.

We see that the Middle Atlantic States and neighboring regions may be warmed owing to an unusual extension westward, or increased intensity of the Atlantic high area, as in 1882, 1894, and 1898; or it may be owing to the retreat northward of the British American high area, as in 1878. In either case there is a comparative absence of the cold northwesterly winds which are a characteristic feature of the normal March, in which there is more or less of a see-saw between the domination of winds from the northwest and those from the southeast. All warm Marches fall into one or the other of these two classes.

Cold Marches.—We come now to the consideration of another class of March conditions, those having mean temperatures decidedly below the normal in the Middle Atlantic States.

March, 1883, Plate VII.—An examination of the chart will show a large area, everywhere east of the 105th meridian, in which the temperatures were below the average. The departures were not large but were uniformly below the normal east of this meridian, and as uniformly above normal from this meridian to the Pacific coast. The striking feature of the pressure distribution was the strength of the continental high area, together with the lack of development of the Atlantic high area in the western portion of the ocean. Such a system brings prevailing northerly or northwesterly winds to all sections in the eastern half of the country. The mild weather resulting from high pressure over the western Atlantic Ocean was absent. The cold and dry northwesterly winds meet with comparatively little opposition in their passage across the country, such as they meet with when the Atlantic high is well marked; there is a deficiency of rainfall, as is distinctly shown by the figures.

March, 1885, fig. 4. — In March, 1885, the line of temperature departure was again in the region of the 100th meridian, with decided minus departures eastward to the Atlantic Ocean and plus departures westward to the Pacific Ocean. The continental high area covers the entire country, with its greatest development over the northern plateau region, considerably to the south of its usual position. Here again the Atlantic high falls short of extending its influence to our coasts; while well developed it is found farther eastward with its axis inclined from southwest to northeast. The continental high again plainly dominates the weather of the United States. The fact that the center of the continental high area is so much farther to the south of its usual position is sufficient explanation to account for the temperatures above normal west of the 100th meridian. With this position of the center the bodily transfer of cold air from the neighborhood of Hudson's Bay does not take place, and hence there would not be the usual frequency of cold northerly winds.

March, 1888.—During this month temperatures were below normal throughout the United States and the Canadian provinces. In Manitoba the departure was minus ten degrees. From this point the departures diminished in all directions to the east, south, and west. In the Middle Atlantic States they were from 3° to 4° below; on the Pacific coast, temperatures were nearly normal. An area of high pressure of unusual intensity covered the greater part of British North America, the pressure over a large portion of this area reaching 30·3 inches. Over the Atlantic Ocean the high area is normally developed both as to its form and intensity, but is found fully ten degrees farther south than its usual position. These two high areas are joined over the United States, giving the Atlantic Ocean high area the appearance of a prolongation of the continental high area; the latter, however, both on account of its great extent, and its steep gradient, clearly controls the situation, throughout the continent. The rainfall was nearly normal in all sections of the country, excepting in the western Gulf States, where there was an excess of about two inches. The permanent low area in the North Atlantic is found fully 20° south of its normal position. Central Europe is found in the center of this depression with all the characteristics of "depression weather."

March, 1891.—In this month we find the average temperatures again below the normal in all portions of the United States. The departures are nearly normal along the Atlantic and Pacific coasts and increase towards the 100th meridian, along which the departures reach minus eight degrees to minus ten degrees. The continental high area extends considerably beyond its normal eastern limit, with approximately normal intensity. Observations were not available to fix the position of the Atlantic high area, but at least its western extremity was but slightly developed, as there is no evidence of it in the pressure observations of the South Atlantic States. The rainfall of the month was nearly normal, excepting in the Middle Atlantic States, the Ohio Valley, and the East Gulf States, where it was considerably in excess of the normal, and upon the Pacific coast, where it was somewhat below.

March, 1897, cold in the extreme northwest, fig. 2.—The temperatures are from 3° to 6° above normal in all sections east of a line running from Duluth to Amarillo, Texas; to the west of this line, the temperatures are all below normal with a maximum departure of minus twenty degrees north of Montana. So far as the eastern States are concerned this belongs to the warm type of March; as, however, the greater part of the country is below normal, and the temperatures in the northwest are phenomenally low, it is described with the cold types. Here we have both the continental high and the Atlantic high with a nearly normal development in intensity but extending somewhat beyond their usual limits. In strength they are apparently equal, the Atlantic high controlling the eastern half of the country and the continental high the western half. On the Pacific coast we find the high area with apparently a normal development but somewhat to the south of its usual position. In the neighborhood of Puget Sound there is a low area. This distribution of pressure on the Pacific coast, together with a fair development of the continental high area appears to be particularly favorable for the production of low temperatures in the extreme northwest, the low pressure near Puget Sound facilitating the transfer of cold air from the interior toward the coast. The rainfall was considerably above normal in the Mississippi and the Ohio Valleys and somewhat above on the Pacific coast; it was below normal on the Atlantic coast within the area enclosed by the isobar of 30·1 inches.

March, 1899, cold in extreme northwest.—The conditions were somewhat similar to those of March, 1897. The temperatures were slightly above normal east of a line running from Boston southwest to Amarillo, Texas; to the west and north of this line, temperatures were everywhere below the normal, the greatest departures being in Montana, where they reached the excessive value of minus twenty degrees. The continental high was strongly developed. Its influence was felt in nearly all sections of the country reaching eastward as far as the lower Lake region and southward to Texas, the normal development of the Atlantic high area checking the further extension of its influence eastward. The rainfall was excessive in the Ohio Valley and Tennessee, in New England and in California; it was deficient in the South Atlantic and Gulf States, and in the neighborhood of Puget Sound.

The months cited above include all those during which there was a marked mean temperature below the normal east of the Mississippi River from 1876 to 1899, and two of extreme departures in the northwest. A characteristic feature of the former is a marked development of the continental high area, or a weak development or absence of the Atlantic high area in the region of the South Atlantic States. Again we notice a deficiency in rainfall in nearly all cases in which the region is clearly within the high pressure area, though this is not so universally true as in the case of the Atlantic high. All these conditions of pressure distribution naturally produce winds prevailingly from a northerly or a westerly direction, which bring with them the severe temperatures of the interior of the continent.

Extent and Intensity of Cold and Warm Periods.—The geographical extent and the amount of departure from the normal temperature are indicated upon the charts. By charting the mean pressure distribution in connection with the lines of equal temperature departure, we see readily why one section of the country may enjoy mild weather while in a neighboring section the weather may be exceptionally severe. We see also that the entire country may at the same time have temperatures considerably above or below normal.

The relation between pressure and rainfall.—Some interesting relations between rainfall and mean pressure conditions have come to light in this investigation. The decidedly cold, as well as the decidedly warm months, were deficient in rainfall. In each case, in the Middle Atlantic States, "high area" weather prevailed, the region being either well within the Canadian high area or well within the Atlantic high area.

The extent and persistence of these areas of high pressure over any region define the geographic limits and the duration of a drought. Should we be enabled, by further study of the problem, to learn the law of movement of these high areas, it will become a comparatively easy problem to forecast periods of drought and of abundant rains in the United States. A similar method is already practiced in India, with a fair measure of success, in forecasting the monsoon and the winter rains.

During months having a rainfall above the normal in the Middle Atlantic States, this region was almost always within a trough of average low pressure, or near the western or northern edge of the Atlantic high area.

Average pressure distribution and the paths of storms.—Some interesting and suggestive points are brought out by charting storm tracks in connection with the mean pressure distribution during the month, and comparing the results with the normal distribution of pressure and storm paths.*

Fig. 1 shows the normal storm tracks during March. As has already been pointed out, during March the continental high and the Atlantic high areas are, within the limits of the United States, quite equally balanced in strength. It will be observed that the storm paths while normal pressure conditions exist, are spread quite uniformly over the country from the Great Lakes to the Gulf, and converge in the neighborhood of Labrador on leaving the United States. I have plotted the storm paths of March in connection with the pressure distribution during several characteristic abnormal departures of pressure. In fig. 2 for March, 1897, they are found in a narrow band extending east and west across the Lakes and down the St. Lawrence Valley. Fig. 3 for March, 1882, shows a crowding together of the storm paths into a comparatively narrow band, extending from northeast to southwest, across the Lake Region and down the St. Lawrence Valley. In fig. 4 for March, 1885, the paths are mostly north of their usual position, with some along the Atlantic coast, while the central portion of the country is comparatively free from storm paths.

Mean pressure distribution and the paths of West Indian hurricanes.—In order to learn whether the path of a West Indian hurricane is to any extent controlled by the prevailing pressure over the Atlantic Ocean during the time of passage of a hurricane, I have selected from Bulletin A of the United States Weather Bureau the path of a hurricane which extended very far inland, and plotted it in connection with the mean September position of the Atlantic high area, together with the position of the area during September, 1886. This West Indian hurricane occupied about eleven days in its passage from

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* F. H. Bigelow. Storms, storm tracks and weather forecasting. United States Weather Bureau, Bull. No. 20. 8°. Washington, 1897. 87 pp.

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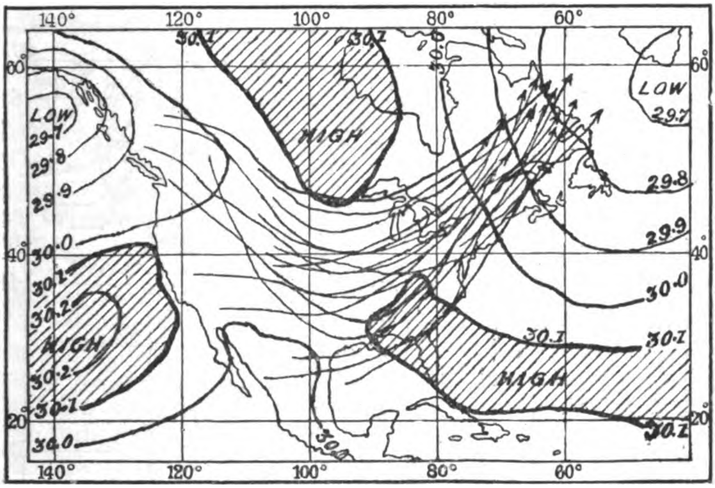

AVERAGE PATHS OF MARCH STORMS.

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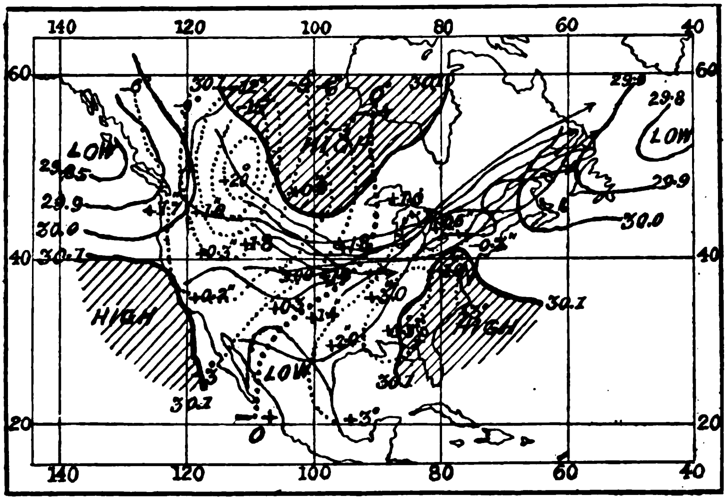

MARCH, 1897.

the West Indies through the Gulf of Mexico, up the Mississippi Valley and across the Lake region. The Atlantic high area extended far to the west of its usual position. Similarly the conditions for September, 1883, were charted, during which a

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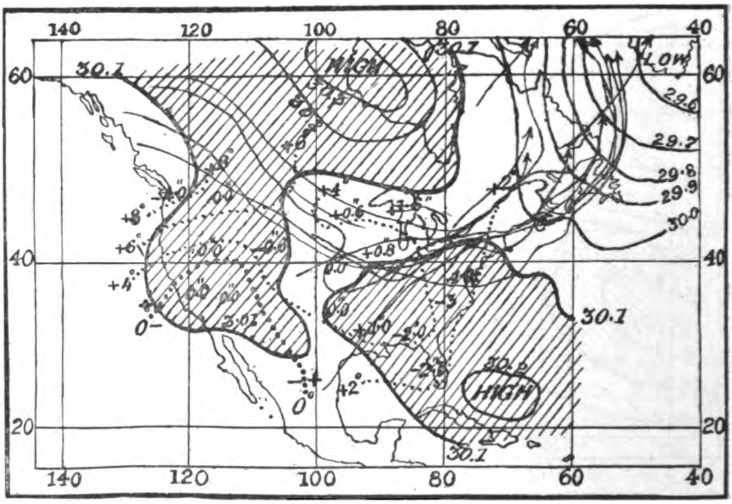

MARCH, 1882.

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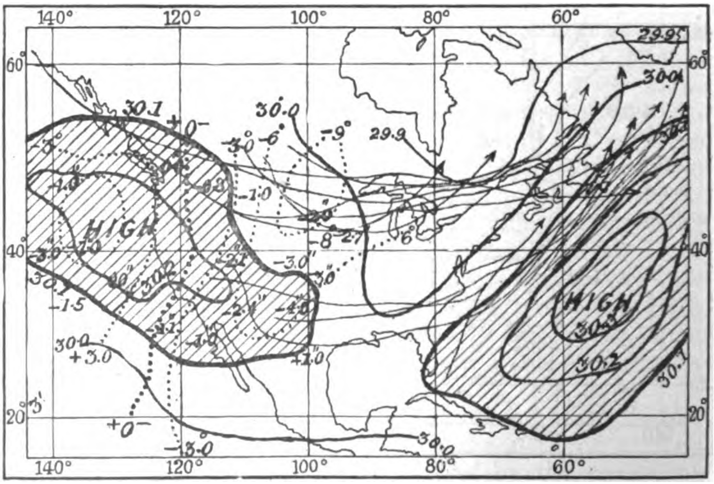

MARCH, 1885.

West Indian hurricane took a path farther to the eastward than usual. The Atlantic high area was well to the east of its usual position. In both cases the path of the hurricane was along the western edge of the Atlantic high area.

These two instances, taken at random, seem to show a direct relationship between the Atlantic high area and the path of the hurricanes. It is quite probable that by charting the pressure conditions over the Atlantic Ocean at the origin and during the slow progress of a hurricane, we may be enabled to forecast more definitely its probable path across the United States.

Summary of results.—The study of March weather conditions in the United States seems to warrant the following statements :

(*a*) The problem of March weather in the United States is a problem of the relative preponderance of the three areas of high atmospheric pressure seen upon the chart of normal pressure and described above.

(*b*) The weather of the Middle Atlantic States is cold when the continental high area controls this region; it is warm when the Atlantic high area extends its influence westward beyond the coast; it is normal when there is a fairly equal development in strength and extent of the two high areas, in which case now one, then the other, is in control of the wind direction, bringing alternately cold and warm air to the region.

(*c*) A complete control of the region by either area is accompanied by a deficient rainfall. The extent and persistence of the high area defines the extent and severity of a drought.

(*d*) The paths of storms lie within the trough between the two high areas ; when the trough is wide the storm paths are widely scattered; as the high areas approach one another the storm paths are contracted within narrower limits.

(*e*) An intelligent discussion of Pacific coast weather demands a better knowledge of the development and movements of the Pacific high area. Under normal conditions during March the weather of the Pacific Coast States is completely controlled by this high area, which sends to these regions warm winds from the ocean. The temperatures and rainfall along the North Pacific coast are far in excess of the normal for those latitudes. An abnormal development of the continental high area will lower the temperature. This will be intensified by the retreat southward or westward of the Pacific high area, and the approach of the Behring Sea low area to the neighborhood of Puget Sound; a condition which brings about a comparatively steep gradient between the coast and the interior, and facilitates the transfer of large masses of cold air from the interior of the continent to the coast.

In order to turn to practical account the facts gathered in the foregoing paragraphs, a better knowledge of the manner in which these high areas move and their rate of movement, is necessary. Excellent material is at hand for the study of these problems in the "Bulletin of Simultaneous International Observations" of the United States Weather Bureau, the "Synoptic Charts of the North Atlantic Ocean" of the Danish Meteorological Institute and the Hamburg Marine Observatory, and the "Charts of the Indian Monsoon Area" of the Indian Meteorological Service. It is of the highest importance to secure synoptic charts of the Pacific Ocean, charts for this vast area being at present entirely wanting. The United States Hydrographic Office has fortunately made a beginning in this direction by collecting daily observations of pressure, wind direction and state of the weather, for use in the preparation of the Pilot Chart of the Pacific Ocean, but these observations are not published and hence not easily accessible for purposes of study.

Some advance has been made in gathering telegraphic statistics for the North Atlantic since Hoffmeyer in 1879 proposed joining the islands of the ocean to the mainland in order to trace more accurately the larger atmospheric movements. In the south-western part of the ocean the chain has been completed by the recent establishment of the West Indian weather service as a branch of the United States Weather Bureau. Several most important links in the chain are still lacking, namely the Azores, Iceland and Greenland.

The necessity of a larger field of view in the study of weather sequences is steadily becoming more apparent to the meteorologist. The hope of progress in weather forecasting lies in this direction.

Johns Hopkins University, Baltimore.

ART. XLI.—*Some new Minerals from the Zinc Mines at Franklin, N. J., and Note concerning the Chemical Composition of Ganomalite;* by S. L. PENFIELD and C. H. WARREN.

THE minerals to be described in the present paper came for the most part from the one-thousand-foot level of the Parker Shaft on North Mine Hill. Unfortunately at the time that they were brought to the surface, about two years ago, the fact that several new species were being mined was not known, and a quantity of material, which it is believed would prove to be very profitable hunting ground for the new species, was thrown upon the dump and subsequently covered up. Our attention has been called to these minerals at different times by Messrs. E. P. Hancock, of Burlington, N. J., J. J. McGovern, of Franklin, F. L. Nason, of West Haven, Conn., F. A. Canfield, of Dover, N. J., and W. M. Foote, of Philadelphia, Pa., while both of the authors at separate visits to the locality have been able to collect a few specimens. The new species were found in a somewhat limited area, and it is especially interesting to note the minerals which are associated with them, for they are very unusual even for Franklin, N. J., and would seem to indicate that peculiar conditions prevailed during the period when these minerals were being formed. The associated minerals are as follows: Native lead* and copper,† clinohedrite,‡ roeblingite,§ axinite in transparent yellow crystals, willemite in exceptionally fine, transparent green crystals, vesuvianite, datolite, barite, garnet, brownish-black phlogopite and a little franklinite. The presence of axinite and datolite containing boron and of phlogopite would seem to indicate that the minerals, part of them at least, have resulted from metamorphism brought about by the action of intruded igneous masses either during the pneumatolitic period when such masses were giving off heated aqueous vapors carrying boron and fluorine compounds, or during a period when heated waters, laden with mineralizing agents, were circulating through the deposit.

1. HANCOCKITE.

This mineral was found in considerable quantity both massive and in cellular masses of a brownish-red or maroon color, and attention has already been called to it as a new species by Penfield and Foote in their description of clinohedrite.‖ Thus far it has been observed only in very small, lath-shaped crystals, the largest being not over 0·5^{mm} in length and 0·15^{mm} in diameter, and these generally are so intimately associated with garnet, axinite and phlogopite that it was for a long time difficult to secure a specimen from which a sufficient quantity of the pure material could be obtained for the chemical analysis. The accompanying figure is a sketch of one of the crystals as seen under the microscope. The faces are striated parallel to the longer axis of the crystals, and they round into one another owing to oscillatory combinations. The terminal faces, necessarily very small, are vicinal, and it has thus far been impossible to find any crystal from which satisfactory measurements of the interfacial angles could be obtained. As may be seen from the figure the habit of the crystals is like that of epidote; that is, the prominent faces are parallel to the axis of symmetry, and the crystals are terminated by two faces corresponding to the form *n* ($\bar{1}11$) of epidote. On one of the crystals it was possible to obtain approximate measurements with the Fuess reflecting goniometer by using a strong illumination of the signal and the δ ocular. The measurements, given in the accompanying table, although not sufficiently accurate for establishing an axial ratio, indicate that the forms and angles of hancockite are similar to those of epidote.

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* This Journal, vi, p. 187, 1898.

† Proc. Am. Acad. of Arts and Sci., xxxiii, p. 429, 1898.

‡ This Journal, v, p. 289, 1898.

§ Ibid., iii, p. 413, 1897.

‖ Loc. cit.

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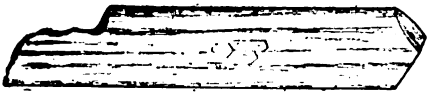

	Hancockite, Approximate measurements.	Epidote.
$c \wedge e$, $001 \wedge 101$ =	36° 15′	34° 43′
$e \wedge a$, $101 \wedge 100$ =	30 45	29 54
$c \wedge r$, $001 \wedge \bar{1}01$ =	63	63 42
$r \wedge a$, $\bar{1}01 \wedge \bar{1}00$ =	55 30	51 41
$n \wedge n$, $\bar{1}11 \wedge 11\bar{1}$ =	67	70 29
$c \wedge n$, $001 \wedge \bar{1}11$ =	77	75 11

Although the appearance of the mineral in the hand specimen varies from a dark to a light brownish-red, single crystals, as seen with a pocket lens, have a yellowish-brown color. Crystals like fig. 1, when examined with the polarizing microscope, exhibit distinct pleochroism, yellowish-brown for vibrations parallel to 𝔟, which corresponds to the crystallographic axis *b*, and somewhat variable for vibrations at right angles to this direction, being delicate rose color at the attached end and grading to pale, somewhat greenish-yellow at the terminated end. On some very small individuals the delicate rose color was observed throughout the whole length of the crystals. With crossed nicols the crystals show an extinction when their longer or symmetry axis is parallel to the plane of the polarizer. In convergent light something of the outer rings of the biaxial interference figure could be seen, accompanied by a dark bar, indicating plainly that the optical axes are in the symmetry plane. By rotating a crystal, when immersed in the potassium mercuric-iodide solution, the optical axes could be brought separately to the center of the field and their divergence 2 V was found to be approximately 50°.

The luster of the hancockite crystals is vitreous, and the hardness is about 6·5–7. Owing to the small size of the crystals and their intimate association with garnet, axinite and willemite, considerable difficulty was experienced in finding a specimen from which a sufficient quantity of pure material could be obtained for analysis. A specimen, however, finally came to us through Mr. Hancock, consisting of a cellular mass in which the walls and the drusy lining consisted chiefly of hancockite. By crushing this specimen, picking out the small fragments and examining them with a lens, it was possible to obtain the mineral almost absolutely free from the associated garnet and axinite, which could be distinguished by their lighter color. An attempt to separate the minerals by differences in their specific gravity was not successful. The specific gravity of the carefully selected material was found to be 4·030.

Concerning the method of analysis the only points which need to be specially commented upon are the following: After separation of the silica, the lead was precipitated with hydrogen sulphide and subsequently converted into sulphate and weighed. The iron and alumina were separated from the bivalent metals by a basic acetate precipitation, reprecipitated by ammonia and weighed as oxides, the iron being estimated subsequently by means of potassium permanganate. The calcium and strontium were converted into nitrates and separated by means of amyl alcohol as directed by Browning.* Water was estimated by loss on ignition. Careful tests failed to reveal the presence of any ferrous iron. The deep color of the crystals at first suggested the idea that the mineral would be rich in manganese, which is by no means the case. The color, however, is probably due to the presence of some higher oxide of manganese which is known to impart an intense color to silicates and was estimated by the method described by Penfield.†

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* This Journal, xliii, p. 50, 1892.

† Ibid , xlvi, p. 291, 1893.

The results of the analysis by Warren are as follows :—

			Average.	Ratio.				Partial Analysis.	
SiO_2	30·99		30·99	·516		SiO_2	6	SiO_2	30·88
Al_2O_3	17·89		17·89	·173	·259	R_2O_3	3·00	Al_2O_3	17·99
Fe_2O_3	12·30	12·37	12·33	·077				Fe_2O_3	12·96
Mn_2O_3	1·38		1·38	·009					---
PbO	18.47	18·59	18·53	·083	·367	RO	4·26	PbO	17·47
MnO	2·12		2·12	·029				MnO	2·96
MgO	0·52		·52	·013				MgO	1·02
CaO	11·50		11·50	·205				CaO SrO	15·33
SrO	3·89		3·89	·037					
H_2O	1·62		1·62	·090		H_2O	1·06		1·62
			100·77						100·23

The ratio of $SiO_2 : R_2O_3 : RO : H_2O$ approximates closely to 6 : 3 : 4 : 1, which gives as the empirical formula $H_2R''_4R'''_6Si_6O_{26}$, or $R''_4(R'''\cdot OH)R'''_2(SiO_4)_6$. The general formula is that of epidote, but the material differs from any variety of that mineral previously described in having the bivalent metals lead and strontium isomorphous with calcium. Owing to its color and the presence of manganese sesquioxide the mineral is allied to piedmontite. It will be observed that the quantity of protoxide, RO, indicated by the analysis, is a trifle high, SiO_2 : RO being 6 : 4·26 instead of 6 : 4, as it should be to satisfy the epidote formula. The analyses, however, were made with very great care, and in the determination of the calcium and strontium the separated oxides were converted into sulphates and thus found to have the correct molecular weight. The partial analysis given was made on material taken from the same specimen as used for the other analysis, but the higher oxide of manganese was not determined and strontium was not separated from the calcium.

In its chemical as well as in its crystallographic relations, hancockite is a member of the epidote group of minerals, and should occupy a position next to piedmontite in a system of mineralogy. It is especially interesting on account of the considerable quantities of lead and strontium which it contains, elements thus far observed in combination with silicic acid in only a few rare mineral species.

Before the blowpipe, hancockite fuses with intumescence at 3 to a black, slightly magnetic globule. The globule becomes more strongly magnetic if heated on charcoal. With sodium carbonate on charcoal a coating of lead oxide is obtained. Reacts for manganese with the sodium carbonate bead in O. F. The mineral is insoluble in hydrochloric acid, but, like epidote, after fusion it dissolves and yields gelatinous silica upon evaporation. In the closed tube, at a high temperature, a little water is given off.

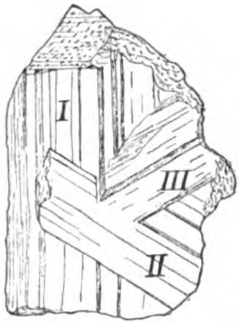
A considerable quantity of hancockite was taken from the mine at one time, and it is the most abundant of the new species described in this paper. It is named after Mr. E. P. Hancock of Burlington, N. J.

2. GLAUCOCHROITE.

This mineral was collected by S. L. Penfield in September, 1898, and was subsequently sent to New Haven for identification by Mr. W. M. Foote, who had collected several specimens of it earlier in the season. It occurs in prismatic crystals belonging to the orthorhombic system, and in columnar aggregates imbedded in a white matrix. The largest crystals thus far observed do not average over 2^{mm} in greatest diameter, while the length of some of the columnar aggregates somewhat exceeds 10^{mm}.

Isolated crystals generally show the form of a prism *m* (110), sometimes in combination with a second prism *s* (120), and thus far all attempts to find a crystal with terminal faces have proved unsuccessful. A few penetration and contact twins have been observed, the twinning plane being the brachydome (011), and the vertical axes of the individuals crossing at angles of about 60° and 120°. Fig. 2 is an illustration of one of these penetration twins, drawn with the camera lucida as it appeared under the microscope. On the twin crystals the pinacoid *a* (100) is generally developed, although it was not observed on any of the simple crystals.

2



The prismatic faces, although bright, were vicinal, and consequently it was difficult to obtain reliable measurements of the prismatic angle. The average of a number of measurements of $m \wedge m$, $110 \wedge 1\bar{1}0$, was found to be 47° 32′, and this angle, taken as fundamental, agreed very closely with the measurements derived from the best reflections. As terminal planes were not observed, the angle between the vertical axes of two prisms in twin position was measured under the microscope and found to be 121°. Assuming the twinning plane to be the brachydome (011), the angle of $011 \wedge 0\bar{1}1$ was thus found to be 59°, and taken as a fundamental angle. From the foregoing fundamental angles the axial ratio has been calculated, and is given below, together with the axial ratios of monticellite and chrysolite, to which species glaucochroite is closely related, it being a manganese monticellite.

Glaucochroite, $a : b : c = 0·440 : 1 : 0·566$
Monticellite, " " " $= 0·431 : 1 : 0·576$
Chrysolite, " " " $= 0·466 : 1 : 0.586$

No reliable reflections could be obtained from the second prism *s* (120). Approximate measurements are $120 \wedge \bar{1}20 = 99°$, calculated 97° 16′ and $m \wedge s$, $110 \wedge 120$, = 17° 21′, calculated 17° 36′. A rather poor basal cleavage was detected, and measurements from this cleavage onto the prism faces gave angles of 90°.

The hardness is about 6. The specific gravity, taken with the pycnometer is 3·407. The fracture is conchoidal. The luster is vitreous and the color is a delicate bluish green, very similar to that of the aquamarine variety of beryl. Minute crystals are almost colorless, and on a few of the specimens there were small areas where the mineral exhibited a delicate pink color.

The optical orientation is $\mathfrak{a}=b$, $\mathfrak{b}=c$ and $\mathfrak{c}=a$. The plane of the optical axes is the base (001) and the acute bisectrix is normal to the brachypinacoid *b* (010). The double refraction is therefore negative. Prismatic crystals served as prisms for determining the indices of refraction $\alpha=1·686$ and $\beta=1·722$. These values were each derived from the mean of four independent measurements which showed considerable variation, owing to the vicinal character of the prismatic faces, but it is believed that they represent a close approximation to the true values. On a section parallel to the pinacoid (010), which measured $0·5 \times 1·5^{mm}$, the divergence of the optical axes for yellow light, Na flame, was measured on the Fuess axial angle apparatus as follows: 2 E=121° 30′ and 2H in α-monobromnaphtalene=63° 27′. From these values $2V_y$ was found to be 60° 53′ and 60° 49′, respectively. The dispersion was marked $\rho > v$. From the values α, β and V, γ was calculated and found to be 1·735. The optical orientation, dispersion and the character of the double refraction of glaucochroite are like those of monticellite as determined by Penfield and Forbes.* The indices of refraction for yellow light and the divergence of the optical axes, 2V, of glaucochroite, monticellite and chrysolite are given below for comparison:

	α	β	γ	$\gamma-\alpha$	2 V over a
Glaucochroite,	1·686	1·722	1·735	0·049	60° 51′
Monticellite,	1·6505	1·6616	1·6679	0·0174	75° 2′
Chrysolite,†	1·661	1·678	1·697	0·036	92° 14′

Very pure material for the chemical analysis was obtained by picking out the small prismatic crystals which separated readily from the matrix. The results of the analysis by Warren are as follows:

		Ratio.		Corrected analysis.	Theory for $CaMnSiO_4$
SiO_2	31·48	·524	1·00	31·98	32·08
MnO	38·00	·535	1·02	38·60	37·97
CaO	28·95	·517	·99	29·42	29·95
PbO	1·74				
FeO	trace			100·00	100·00
	100·17				

Leaving out of consideration the small amount of PbO, which, owing to its high molecular weight, had only a slight effect upon the ratio, the ratio of SiO_2: MnO: CaO=1·00: 1·02: 0·99, or a very close approximation to 1:1:1. The formula of glaucochroite is therefore $CaMnSiO_4$, that of monticellite being $CaMgSiO_4$. With the above analysis we have given the corrected analysis, after disregarding 1·74 per cent of PbO and calculating to 100 per cent, and also the theoretical composition corresponding to the formula $CaMnSiO_4$. Glaucochroite takes therefore a place in the system of mineralogy next to monticellite as a member of the chrysolite group.

Glaucochroite fuses quietly before the blowpipe at about 3·5 to a brownish black globule, and imparts no color to the flame. The powdered mineral dissolves easily in hydrochloric acid, and the solution yields gelatinous silica upon evaporation. A little of the concentrated solution, when brought in contact with a drop of sulphuric acid on a watch glass, gives a precipitate of calcium sulphate. With either the borax or sodium carbonate beads a strong reaction for manganese is obtained.

So far as known, only a small amount of glaucochroite has been found. Its crystals occur imbedded in a white matrix, nasonite (see beyond), and intimately associated with brown garnet and yellow axinite. The name glaucochroite has been given to this species because of its color, from γλαυκός = *blue-green* and χροια = *color*.

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* This Journal, 1, p. 135, 1896.

† Des Cloizeaux, Memoirs de l'Institute de France, T. xviii, p. 591.

3. NASONITE.

This material constitutes the matrix in which the crystals of glaucochroite are generally imbedded. It occurs massive, of white color, greasy to adamantine luster, hardness about 4, and hand specimens usually present a mottled or spotted appearance owing to numerous inclusions of yellow axinite and brown garnet, which are scattered rather uniformly through the massive nasonite. The material that has been examined consists of a few specimens collected by S. L. Penfield and some sent to us by Mr. W. M. Foote.

Thin sections when examined with the polarizing microscope show that the material is crystalline, and that the masses consist of an intergrowth of crystal particles, some of which are several millimeters in diameter. No pronounced cleavages were observed under the microscope, and no crystal boundaries were detected which gave any clue to the system of crystallization. In convergent polarized light, however, certain sections gave a uniaxial interference figure, and, since the massive mineral broke up at times into rude rectangular blocks, it may be inferred that the crystallization is tetragonal and that the cleavage, which is poor, is prismatic and basal. The birefringence is rather strong, and the character of the double refraction is positive.

Material for the chemical analysis was obtained by crushing a large fragment and picking out the purest material by hand. The specific gravity was found to be 5·425, and the results of the analysis by Warren are as follows:

	I	II	Average	Ratio		
SiO_2	18·47	18·47	18·47	·308		3·00
PbO	65·84	65·52	65·68	·294	·516	5·03
ZnO	0·84	0·80	0·82	·010		
MnO	0·90	0·76	0 83	·011		
FeO	0·10	——	0·10	·001		
CaO	11·20	11·20	11·20	·200		
Cl	2·80	2·82	2·81	·079	·108	1·05
H_2O	0·27	0·26	0·26÷9	·029		
			100·17			
Oxygen equivalent of Cl			·63			
			99·54			

The ratio of SiO_2 : (Pb+Zn+Mn+Fe+Ca) O : (Cl+OH) = 3·00 : 5·03 : 1·05 which approximates closely to 3 : 5 : 1, and, since two chlorine atoms are equivalent to one oxygen, this leads to the general formula $R_{10}Cl_2Si_6O_{21}$, R = Pb and Ca, and only traces of Zn, Mn and Fe. Before discussing the general formula further, it may be stated that there were observed, intimately associated with the nasonite, a few particles of clinohedrite, $H_2CaZnSiO_5$, and it is probable therefore that the small percentage of zinc (0·82 per cent ZnO) was derived from a slight admixture of this latter mineral. It seems therefore best to deduct from the foregoing analysis the ZnO, and sufficient amounts of SiO_2, CaO and H_2O to form the clinohedrite molecule. The ratio then becomes SiO_2 : (Pb+Mn+Fe+Ca) O : (Cl+OH) = ·298 : ·496 : ·098 = 3·00 : 5·01 : 0·99 or almost exactly 3 : 5 : 1. Furthermore the ratio of SiO_2 : PbO : (Ca+Mn+Fe) O : (Cl+OH) = ·298 : ·294 : ·202 : ·098 = 3·00 : 2·97 : 2·04 : 0·99 or, very closely, 3 : 3 : 2 : 1. Since Fe, Mn, and water (hydroxyl) are present only in very small amounts, they may practically be disregarded, and the empirical formula expressed as $Pb_6Ca_4Cl_2(Si_2O_7)_3$, or $Pb_4(PbCl)'_2Ca_4(Si_2O_7)_3$.

Below we have given the analysis, after deducting 2·16 per cent of clinohedrite, substituting for MnO and FeO equivalent amounts of CaO, for the remaining 0·09 per cent of water (hydroxyl) an equivalent of chlorine, and calculating to 100 per cent, while, for comparison, the theoretical composition corresponding to the formula $Pb_6Ca_4Cl_2(Si_2O_7)_3$ is also given.

	Analysis corrected.	Theory.
SiO_2	18·32	18·21
PbO	67·32	67·68
CaO	11·59	11·33
Cl	3·57	3·59
	100·80	100·81
O = 2Cl	·80	·81
	100·00	100·00

Before the blowpipe, nasonite is very apt to decrepitate, but if a fragment can be held in the forceps it fuses at about 2 to a semi-transparent globule, and the characteristic flame coloration of lead is obtained. In the closed tube the mineral gives a trace of water and an abundant sublimate of lead chloride, the residual mineral fusing to an amethystine glass in the bottom of the tube. The powdered mineral, when heated alone on charcoal in the reducing flame, gives a white sublimate of lead chloride distant from the assay, a yellow coating of oxide nearer, and globules of metallic lead. The mineral is readily soluble in dilute nitric acid, and the solution yields gelatinous silica upon evaporation.

The mineral is named after Mr. Frank L. Nason of West Haven, Connecticut, formerly of the Geological Survey of the State of New Jersey.

Note concerning the Chemical Composition of GANOMALITE.

Nasonite is closely related to ganomalite, to which the empirical formula $Pb_2Ca_2Si_2O_{11}$ has been assigned, a little calcium being replaced by manganese. The foregoing formula, when doubled, may be written as a slightly basic salt, as follows: $Pb_4(Pb_2O)''Ca_4(Si_2O_7)_3$, which is like the formula of nasonite, except that the bivalent basic lead oxide radical (Pb_2O) of ganomalite takes the place of the two univalent lead chloride radicals (PbCl) of nasonite. The analogy between the two minerals, however, becomes still closer if two univalent lead hydroxide radicals (PbOH) are substituted for the bivalent basic lead oxide radical as follows: $Pb_4(PbOH)_2Ca_4(Si_2O_7)_3$, and we hope to be able to show that this is undoubtedly the correct formula for ganomalite. The amount of water necessary to yield two hydroxyls in the complex ganomalite molecule is a trifle less than one per cent, a quantity which might have been easily overlooked. In two analyses of ganomalite from Jakobsberg, Sweden, by Wiborgh, quoted by Sjögren,* neither water nor loss on ignition are recorded, while in an analysis by Lindström† a loss on ignition of 0·57 per cent is given, and, what is also very significant, the presence of a little chlorine is recorded. Lindström's analysis is as follows:

	Analysis.	Ratio.				Analysis recalculated.	Theory for $Pb_4(PbOH)_2Ca_4(Si_2O_7)_3$
SiO_2	18·33		·306	3·00	SiO_2	18·51	18.56
PbO	68·80		·308	3·02	PbO	69·46	68·97
MnO	2·29	·032	·202	1·98	CaO	11·40	11·55
MgO	·11	·003			H_2O	·63	·92
CaO	9·34	·167					
Cl	·24	·007	·070	0·70		100·00	100·00
Ign.	·57 ÷ 9 =	·063					
‡X	·35						
	100·03						

The ratio of SiO_2 : PbO : CaO : (OH+Cl)=3·00 : 3·02 : 1·98 : 0·70 or, excepting the hydroxyl and chlorine, a very close approximation to 3 : 3 : 2 : 1, thus agreeing with the ratio of nasonite.

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* Geol. För. Förhandl., vi, p. 537, 1883.

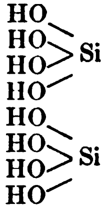
† Ibid., p. 663.

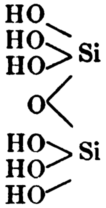
‡ X=CuO 0·02, Al_2O_3 0·07, Fe_2O_3 0·12, alkali 0·10, P_2O_5 0·04.

The water (loss on ignition) is low, owing undoubtedly either wholly or in part to the partial oxidation of the manganese during ignition. It is also possible that a trace of fluorine was present, since the amount necessary to bring the ratio of (OH+Cl+F) up to 1 would be trifling and might easily be overlooked. In connection with Lindström's analysis we have given his values recalculated to 100 per cent, after substituting an equivalent of CaO for the small amounts of MnO and MgO, an equivalent of water (hydroxyl) for chlorine, and disregarding the 0·35 per cent designated as X. The theoretical composition corresponding to the formula $Pb_4(Pb.OH)_2Ca_4(Si_2O_7)_3$ is also given, and, except for the water, which is 0·31 per cent low, the agreement between the recalculated analysis and the theory is most satisfactory.

Ganomalite is tetragonal, and, in all probability, nasonite crystallizes in the same system, for, as already stated, the latter is optically uniaxial and breaks out into rude rectangular blocks, corresponding to the form produced by a combination of the prismatic and basal cleavages. The cleavage of nasonite, however, should be designated as poor, scarcely distinct, while ganomalite is described as having distinct cleavages parallel to the prism *m* (110) and the base. Both minerals exhibit strong positive birefringence. The specific gravity of nasonite, 5·425, is less than that of ganomalite, 5·738, which would be expected, for, although nasonite contains chlorine which is heavier than hydroxyl, ganomalite contains more lead and hence should be heavier. The percentages of lead according to theory are, respectively, nasonite 67·28 and ganomalite 68·98. Thus in their physical properties nasonite and ganomalite are closely analogous, and it may be confidently expected, on the one hand, that if crystals of nasonite are discovered they will be tetragonal, thus conforming to ganomalite, while, on the other hand, ganomalite will be found to contain water in sufficient quantity to yield with the chlorine a ratio of $SiO_2:(OH+Cl)=3:1$. The two minerals furnish an excellent example of the isomorphous relation existing between chlorine and hydroxyl in complex molecules, nasonite being essentially the pure chlorine compound but containing a trace of hydroxyl (water), and ganomalite being essentially the pure hydroxyl compound but containing a trace of chlorine. Both minerals contain a little manganese isomorphous with the calcium.

The acid, $H_6Si_2O_7$, of which nasonite and ganomalite are salts, is intermediate between orthosilicic acid, H_4SiO_4, and metasilicic acid, H_2SiO_3, and it may be regarded either as equivalent to their algebraic sum, or as derived from two molecules of orthosilicic acid by taking away one molecule of water. The latter relation may be expressed as follows:


Two molecules of orthosilicic acid.


Intermediate or mesosilicic acid.

The intermediate acid $H_6Si_2O_7$ is one which has been recognized by mineralogists, but its salts have not generally received a prominent place in the systematic classifications of silicates, because they are not very numerous. Groth* calls attention to the acid and its salts, and has given the name "*Diorthokieselsäure*" to the acid. Clarke† also has discussed the chemical relations of the minerals of this group, adopting Groth's name *diorthosilicic acid*, and calling the minerals *diorthosilicates*. The name *diorthosilicic* seems, however, inappropriate, since $H_6Si_2O_7$ is not an orthosilicic acid as the name signifies, but a derivative of orthosilicic acid. We feel, therefore, warranted in suggesting new names, *mesosilicic* for the acid and *mesosilicates* for its salts, the prefix *meso* being derived from *μέσος*, signifying middle or between. The intermediate relation of mesosilicic acid is evident from the following:

Orthosilicic acid, two molecules,	$H_8Si_2O_8$.
Mesosilicic acid,	$H_6Si_2O_7$.
Metasilicic acid, two molecules,	$H_4Si_2O_6$.

The mesosilicates are classed by Dana in the small group of "Intermediate Silicates" on page 416 of his Mineralogy, and by Groth as "*Intermediäre Silikate*" on page 138 of his *Uebersicht der Mineralien*.

The commonest mesosilicate is iolite, the composition of which may be expressed as a slightly basic salt, as follows: $(Mg, Fe)_4 Al_6 (Al . OH)_2 (Si_2 O_7)_5$, although the two hydroxyls may be in combination with the bivalent metals instead of with the aluminium. One of the few lead silicates, barysilite, $Pb_3Si_2O_7$, is a normal salt of mesosilicic acid, as is also the Franklin mineral hardystonite, $Ca_2ZnSi_2O_7$, recently described by Wolff.‡ Hardystonite is said to occur at the Parker shaft, North Mine Hill, but we have not yet observed it associated with any of the new minerals described in the present paper.

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* Tabellarische Uebersicht der Mineralien, IV Auflage, pp. 105 and 140.

† Constitution of the silicates; Bull. of U S. Geolog. Survey, No. 125, p. 81.

‡ Proceedings of the Am. Acad. of Arts and Sci., xxxiv, p. 479, 1899.

4. LEUCOPHŒNICITE.

This mineral made up the larger part of a specimen about two inches in length and breadth by one inch in thickness, which was found by Mr. J. J. McGovern of Franklin, and given to C. H. Warren in 1897. It has also been observed in small amount on a few specimens sent to us by Mr. W. M. Foote. The mineral has a crystalline structure, vitreous luster, hardness about 5·5–6, and is conspicuous on account of its light purplish-red or raspberry color. It was supposed at first to be clinohedrite, rather deeply colored by manganese. It is intimately associated with willemite of almost gem-like quality and beautiful light green color, and with small idiomorphic crystals of brown vesuvianite, showing prisms of the first and second order, pyramid of the first order and base. Occasional crystal faces were observed on the leucophœnicite, but none which gave any clue to the system of crystallization.

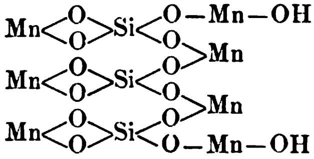
When small fragments of the mineral are imbedded in balsam and examined with the microscope it may be seen that the fragments are mostly irregular, although some are flat and appear to lie upon imperfect cleavage faces. There also may be seen irregular cracks indicating a second but not distinct cleavage. In polarized light the extinction seemed to be slightly inclined to the direction of the second cleavage, and in convergent light an optical axis was observed near the limit of the field. The fragments showed a slight pleochroism, pale rose for vibrations parallel to the direction of cleavage, and colorless at right angles to this direction. These properties indicate that the material probably crystallizes in one of the inclined systems, although wholly satisfactory conclusions could not be drawn.

Very pure material for the chemical analysis was obtained by crushing a portion of the best specimen, and selecting the purest particles by hand. The specific gravity was found to be 3·848. The results of the analysis by Warren are as follows:

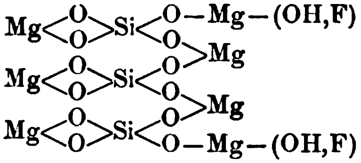
	I.	II.	Average.	Ratio.		
SiO_2	26·31	26·41	26·36	·439		3·03
MnO	60·59	60·67	60·63	·854	1·015	7·00
ZnO	4·03	3·72	3·87	·047		
FeO	----	----	trace	----		
MgO	0·21	----	0·21	·005		
CaO	5·64	5·70	5·67	·101		
Na_2O	0·39	----	0·39	·006		
K_2O	0·24	----	0·24	·002		
H_2O	2·70	2·58	2·64	·146		1·01
			100·01			

Letting R stand for the metals (chiefly manganese) the ratio of $SiO_2 : RO : H_2O$ is 3·03 : 7·00 : 1·01, or a close approximation to 3 : 7 : 1, and this leads to the general empirical formula $H_2R_7Si_3O_{14}$. Since water is not expelled from the mineral much below a red heat, the hydrogen must exist in the form of hydroxyl, and, consequently, the foregoing formula may be written $R_6(R.OH)'_2(SiO_4)_3$ or as a basic orthosilicate, exactly equivalent to humite except that no fluorine is present. Considering the base wholly as manganese, the following is suggested as a structural formula of the mineral, which certainly appears simple and reasonable, and for comparison the structural formula of humite is also given.

Leucophœnicite.



Humite.



Leucophœnicite is therefore a manganese humite, but it contains no fluorine isomorphous with the hydroxyl. As humite is a magnesium mineral resulting from metamorphism due to fumerole or pneumatolitic action, so leucophœnicite is a similarly constituted mineral, produced probably by like causes at a locality where manganese was abundant. It is probable that the crystallization of leucophœnicite is analogous to that of the minerals of the humite group, and, since the examination of fragments of leucophœnicite in polarized light indicated one of the inclined systems (page 351), it may be inferred that its crystallization is monoclinic, with $\beta=90$, analogous to chondrodite and clinohumite, rather than orthorhombic like humite. Furthermore, the discovery of this mineral suggests the possibility of finding a series of manganese compounds, corresponding to prolectite, chondrodite, humite and clinohumite. Attention may also be called to the fact that Jannasch and Locke* have described a variety of humite from Valais, Switzerland, exactly analogous to leucophœnicite in that it contains no fluorine.

Before the blowpipe, leucophœnicite fuses quietly at about 3 to a brownish black globule. In the closed tube it yields a little water. Reacts for manganese with the fluxes. The powdered mineral dissolves very easily in hydrochloric acid, and the solution yields gelatinous silica upon evaporation.

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* Zeitschr. für anorganische Chemie, vii, p. 92, 189.

The name leucophœnicite has reference to the color of the mineral, and was derived from λευκόσ = pale or light and φοίνιξ = purple-red.

There are other minerals from the locality, some of them evidently new, which have been partially examined, and it is hoped that a full description of them may be given in a future article.

In closing we desire to express our thanks to those gentlemen, named at the beginning of this article, who have generously supplied us with material for carrying on this investigation, and especially to Mr. W. M. Foote, who spent some weeks collecting at the locality in the summer of 1898 and who has called our attention to a number of interesting specimens and associations.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School of Yale University, September, 1899.

ART. XLII.—*The Action of Acetylene on the Oxides of Copper;* by F. A. GOOCH and DEFOREST BALDWIN.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIX.]

IN a recent paper by Erdmann and Köthner* an account is given of the formation of a peculiar, light-brown, highly voluminous substance by the action of acetylene below 250° C. upon cuprous oxide, or even (though more slowly) upon copper. The product obtained by passing acetylene during eighteen hours over 1 grm. of cuprous oxide (prepared from copper sulphate, grape sugar, and sodium hydroxide) amounted to 7 grms. and filled a space of nearly 300^{cm^3}. At higher temperatures a black carbonaceous mass is the result, and at red heat (400°–500° C.) carbon is deposited in graphitic condition. The light-brown fluffy material yielded cuprous chloride to hydrochloric acid, a distillate from its mixture with zinc dust possessing the characteristics of naphthene or, at higher temperature and under rapid heating, aromatic compounds among which naphthalene and a kresol were indicated. Erdmann and Köthner classify this body as a very complex but non-explosive copper acetylene (acetylen-kupfer), and from their analyses deduce the formula $C_{44}H_{64}Cu_2$. Apart from the unusual constitution of this symbol, its most striking peculiarity is that it implies a loss of carbon, rather than hydrogen, from the acetylene in the reaction with cuprous oxide—a condition of affairs which would be most remarkable in the light of Campbell's experience,† according to which acetylene passed over palladinized copper oxide yielded water at 225°–230° and carbon dioxide only when the temperature rose to 315°–320° with the formation of a black deposit. Upon scrutinizing the figures of Erdmann and Köthner with care, however, it appears that the formula given by these investigators rests upon some oversight in calculation: the ratio of carbon atoms to hydrogen atoms proves to be actually, according to the data given, 6·45 : 5·70 ; which means, of course, that the new product is deficient, as would be expected, in hydrogen (not in carbon) as compared with acetylene.

As to the content of the new substance in copper, the analytical data are unfortunately ambiguous: for we note the weights found of *copper oxide* converted into percentages of *copper* without preliminary reduction. If the fault is typographical and in the analytical data, the calculated percentages of copper being correct, the average percentage of copper amounts to 15·43 : if, on the other hand, the analytical data are right, the error being in their reduction, the percentage of copper amounts to 12·92. In the one case the summation of the analysis leaves a deficiency of about 1·5 per cent, and in the other of about 4 per cent, which in either case may really represent oxygen in the substance. This condition of matters leaves the "acetylen-kupfer" of Erdmann and Köthner in uncertain standing.

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* Zeitschr. für anorg. Chem., xviii, 49.

† Amer. Chem. Jour., xvii, 690.

More than thirty years ago it was noticed by Berthelot* that acetylene is polymerized by heat or decomposed partially into carbon and hydrogen, and that such action takes place more readily and at lower temperatures in presence of metallic iron with production of carbon, hydrogen and compounds different from those formed by heat alone.

Moissan and Moureu† have observed the incandescence of acetylene passed over finely divided iron, cobalt, nickel or platinum at the ordinary temperature, with production of carbon, hydrogen, and pyrogenic compounds, and have found the occasion of such behavior in the porosity of the metals employed.

It would seem natural, however, that the presence of oxygen, free or combined, may also play a considerable part in such phenomena, just as appears to be the case in the peculiar action recorded by Gruner‡ of carbon monoxide upon iron reduced by hydrogen, which, as Moissan has shown,§ is produced pure only with the greatest precaution and generally carries a large proportion of ferrous oxide. The fact that the "acetylen-kupfer" of Erdmann and Köthner is produced more easily by the action of cuprous oxide upon acetylene than by the action of metallic copper upon acetylene, suggests that it may be the oxidizing power of the cuprous oxide which gives to this reagent its peculiar activity. The question arises, therefore, as to whether the copper is in reality an essential constituent of the compound of Erdmann and Köthner.

In our experiments upon the action of acetylene upon the oxides of copper (and other elements) we have conducted the gas (made in the ordinary way by the action of water on calcium carbide, and kept over water) over the oxide contained in a porcelain boat placed within a glass tube, 2^{cm} in diameter and 50^{cm} long, which was heated over a small combustion furnace. The glass tube was fitted at each end with a rubber stopper, one carrying a smaller tube for the introduction of the acetylene and a high-temperature thermometer so held that its bulb rested horizontally immediately over the boat containing the oxide, while the other was fitted with a water-trap. In the preliminary experiments no attempt was made to purify the acetylene employed other than to keep it over water, or, since water is a product of its action upon oxides, to dry it: in later experiments to secure products for careful analysis it was dried and purified with care.

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* Ann. d. Chim. et d. Phys. [4], ix, 448.

† Compt. Rend., cxxii, 1240.

‡ Ann. d. Chim. et d. Phys. [4], xxvi, 5.

§ Ann. d. Chim. et d. Phys. [5], xxi, 199.

We found that 225° C. is the temperature most favorable for the formation of the voluminous product obtained by acting with acetylene upon cuprous oxide as described by Erdmann and Köthner. At this temperature the tube is choked rapidly with the fluffy product and water forms, but, as Campbell found in his experiments upon palladinized copper oxide, no appreciable amount of carbon dioxide is produced. The content of the product in copper varies in the sample and in different experiments, our results lying between 1·54 per cent and 24·21 per cent of the substance taken for ignition.

It appeared, also, that the action of acetylene upon cupric oxide is precisely similar to that upon cuprous oxide excepting the evident reduction of the former oxide early in the action. The amount of copper in the product of such action varied in our experiments from 6·53 per cent to 21·30 per cent. In one case the experiment of re-submitting to the action of acetylene a product containing 9·34 per cent of copper was made with the result that a new growth of the substance formed which on analysis yielded 3·87 per cent of copper.

A roll of copper gauze carefully reduced in hydrogen and then oxidized at one end in the outer flame of a Bunsen burner gave, when acted upon by acetylene at 225°–250° C., the characteristic deposit upon the oxidized end only, the unoxidized end being merely discolored.

These results go to show that, while metallic copper may at comparatively high temperatures induce the polymerization of acetylene, it is an oxidizing action which starts at moderately low temperatures the formation of the peculiar derivatives under consideration. Thus we find that ferric oxide heated in acetylene at temperatures varying from 150° to 360°, according to circumstances, darkens, glows, and gathers with evolution of heat a dark carbonaceous deposit. In the products of such action we have found the content of iron varying from 2·80 per cent to 5·86 per cent.

Silver oxide, too, acts upon acetylene: thus, in one experiment, action was evident at the ordinary atmospheric temperature, a violent explosion, which completely shattered the boat and scattered metallic silver upon the sides of the glass tube, following before the temperature reached 100°.

In the locally violent explosion of the last experiment we have evidence of the formation in the early stage of an acetylide which is decomposed later when the temperature of dissociation is reached. In the experiments with the oxides of copper and iron the temperature at which the acetylene begins to act is evidently above the point at which sensitive acetylides would naturally dissociate, and we have in the observed phenomena no evidence of the formation of such compounds of copper and iron under the conditions of experimentation.

In experiments (1) to (3) of the following table are given the results of the analysis of several products obtained by conducting acetylene (purified by passing through a solution of mercuric chloride in hydrochloric acid and dried over caustic potash) over pure cuprous oxide. The temperature was kept in these experiments at 225°, and in the course of a half hour the tube was choked completely by material compacted by the pressure to (1) a spongy mass of light-brown color on the exterior next the walls of the tube, (2) darker within and (3) nearly black in the bottom of the boat, where the cuprous oxide lay originally.

In experiments (4) and (5) the substances analyzed represent the products of the action of acetylene (not specially purified) on cupric oxide.

Weight of substance taken. grm.	Found.			Calculated.			
	CO_2 grm.	H_2O grm.	CuO grm.	C grm.	H grm.	Cu grm.	O by difference grm.
(1) 0·1170	0·3978	0·0673	0·0022	0·1085	0·0075	0·0018	—0·0008
(2) 0·2247	0·7489	0·0979		0·2042	0·0109		
(3) 0·1096	0·3678	0·0488	0·0045	0·1003	0·0054	0·0036	0·0003
(4) 0·1360	0·4116	0·0579	0·0182	0·1123	0·0064	0·0146	0·0027
(5) 0·1188	0·3098	0·0461	0·0317	0·0845	0·0051	0·0253	0·0039

	(1)	(2)	(3)	(4)	(5)
Per cent of carbon....	92·74	90·88	91·51	82·57	71·13
" hydrogen .	6·41	4·85	4·93	4·71	4·29
" copper ...	1·54		3·29	10·74	21·30
" oxygen ...	....		0·27	1·98	3·28
	100·69		100·00	100·00	100·00

The oxygen present in these products is obviously proportional to the amount of copper and is never more than enough to be completely accounted for upon the supposition that some of the original oxide taken still holds its oxygen. So far as the analyses show, the product of lightest color (1) contains very little copper and no oxygen; the darkest product (3) obtained from the cuprous oxide contains oxygen corresponding to a mixture of two parts of copper with three parts of cuprous oxide; the oxygen in the products of (4) and (5) obtained by acting upon cupric oxide is approximately enough to correspond to a mixture of cuprous and cupric oxides in equal proportions. This fact, taken in connection with the great range of variation in proportion and the minimum to which the copper falls in the product, which would be least likely to include contaminating metal or oxide, suggests very strongly the probability that the oxygen present is in union with copper and that the copper is held mechanically as metal or oxide and is not the essential constituent of an organic compound. Leaving out of consideration, therefore, the copper and copper oxides, and calculating the composition of the products assumed to consist essentially of carbon and hydrogen, we derive the following statement:

	(1)	(2)	(3)	(4)	(5)
Per cent of carbon....	93·54	94·93	94·88	94·60	94·31
Per cent of hydrogen..	6·46	5·07	5·12	5·40	5·69
	100·00	100·00	100·00	100·00	100·00

These figures correspond to symbols varying from $C_{12}H_{10}$ to nearly $C_{16}H_{10}$, with an average approximating $C_{14}H_{10}$, the symbol of anthracene or paranthracene. The analytical data of Erdmann and Köthner point in the average to a product corresponding more nearly to the first of these symbols than to either of the others. The product is doubtless variable with the temperature and the activity of oxidation. Thus, in one experiment in which acetylene was passed over ferric oxide the action began at 365° with incandescence, as described by Moissan and Moureu,* and the analysis of the product (carbon = 91·53, hydrogen = 1·36, Fe = 5·85, O = 1·26) indicates a proportion of carbon to hydrogen about four times as great as that of the average product of action at 225° on the oxides of copper.

Finally, we find no evidence that the product of the action of acetylene on the oxides of copper under the conditions of our experimentation is other than a mixture of a hydrocarbon or hydrocarbons with metallic copper or an oxide of copper, and, probably, in the darker preparations, some free carbon.

* Loc. cit.

ART. XLIII.—*Andesites of the Aroostook Volcanic Area of Maine;*[*] by HERBERT E. GREGORY.

ANDESITES are rare rocks in the eastern United States, but are the most abundant extrusives so far found in northern Maine. They form prominent hills and determine the general topography in some places, while in others they are represented by isolated remnants among the sedimentaries. The greater number of occurrences are of lava and breccia, but andesitic ash and tuff are also found well developed. In the following descriptions only the more important localities will be dealt with in detail. The andesites are located in Aroostook County in the townships of Chapman, Mapleton, and Castle Hill, where they constitute prominent ridges, known as Edmund's Hill, Hobart Hill and Castle Hill, and several less noticeable masses.

Field Description.

Edmund's Hill Andesites.—Edmund's Hill is situated in Chapman township near the middle of the north township line, and is simply the highest part of a ridge running N.-S. for several miles. The hill itself rises some 200 feet above the road at its base and presents the outline of a drumlin—so evenly has it been graded at each end. The trees, brush, talus, and glacial deposits entirely conceal the formations about the base of the hill, and it is only after climbing half the distance to the top that the bare rock is found in place. In climbing up the west side of the hill fragments of fossiliferous sandstone were found amongst the andesite blocks, and about 100 feet below the top the sandstone ledge outcrops. The thickness and extent of the sandstone could not be determined accurately because covered in so many places with heavy blocks and small fragments of the igneous rock fallen down from above. The contact was not seen. The entire top of the hill is of augite-andesite. The main mass is uniform in texture and cut by cleavage cracks into large blocks, which, when they fall down the slope, remain as huge masses. The south and north ends, however, and part of the west side are quite different. Here the rock is split up into long, thin slabs by a set of parallel cracks remarkably uniform in direction and length, and they retain their parallelism even when the rock is folded or faulted. Cross cleavages intersect these cracks every few feet, so that when the rock is loosened it comes out in flat slaty pieces one-quarter inch or so in width and several inches or even feet in area. The whole appearance is that of thin-bedded sedimentaries which have been folded and faulted. The general direction of these cleavage planes is N. 30° E. on north end and N. 35° E. on south end with a dip southeast at a high angle. The fault planes strike N. 70° E. and besides their effect at the ends of the hills in cutting out the thin slabs they occur all along the west side, each indicating a slight movement. It seems probable that the Edmund's Hill ridge owes its origin in part to the formation of a fault block.

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[*] A portion of a thesis on the "Geology of the Aroostook volcanic area of Maine" presented for the doctorate degree at Yale University in 1899. The full report will appear later as a publication of the U. S. Geological Survey, to which, under the direction of Prof. H. S. Williams, the author owes the opportunity of making the investigations here recorded.

The outlying knobs and hills to the east of the main mass are also of andesite, usually microcrystalline, but sometimes porphyritic. The igneous rock does not extend far to the west, but is replaced by arenaceous slates, and while no precise boundaries of the formation were determined, the field relations suggest that the hill is the remnant of a lava flow over the eroded and upturned edges of sandy rocks of Silurian age.*

Andesites of Hobart Hill.—This hill is an isolated mass of andesite forming a prominent feature in the landscape as one looks west from Presque Isle village. It is situated partly in Mapleton and partly in Chapman townships, and is surrounded entirely by low, poorly-drained swamps and forest lands, and visited only for lumber and tan-bark, which are secured in limited quantities during the winter season. The hill is about 1¼ miles long and ¾ miles wide, and rises quite abruptly above the plain to a height of 300 feet as a single well defined mass without branches or outlyers. The sides are everywhere quite steep, and in places present cliffs forty to fifty feet high. The top is bare only where fire has recently destroyed the vegetation. The talus slopes present a confused mass of large and small blocks of andesite which entirely conceal all outcrops except where cliffs are exposed. On the west and north sides numerous bowlders of red sandstone and conglomerate are piled along the slope and mingled with the volcanic material. These were traced to their parent ledges scarcely a half mile to the north, and the bowlders serve to cover the contact of the andesite with the Mapleton sandstone.† Specimens collected from various places on the hill show but slight differences in composition and texture except the rock from the northwest corner, which is a breccia of andesitic fragments and seems to be situated along a fault line. As was the case with Edmund's Hill, so here, no actual contact between formations was observed, but the sedimentaries were traced to the very base of the hill, and the facts indicate that the hill is a remnant of a lava flow.

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* The sandstone at Edmund's Hill contains an Eodevonian fauna which corresponds closely with that of the Gaspé sandstone. I have given it the name Chapman sandstone.—H. S. Williams.

† The "Mapleton sandstone" here referred to is a massive, and in places coarse, red sandstone, in which plants (Psilophyton, etc.) have been found. It is of Devonian age but somewhat younger than the Chapman sandstone—H. S. W.

Andesites of South Mapleton.—In addition to the prominent hills of andesite just mentioned, there are some ten or twelve less conspicuous outcrops in the southern part of Mapleton township crossed by the Mapleton–Presque Isle road and located in the fields to the north and the south of this road. They occur usually as narrow ridges, and seem to be remnants of lava flows which occupied former valleys, but are now left standing because of the erosion of the sedimentaries on both sides.

Andesites of Castle Hill.—Castle Hill is the local name for the northern end of the high, narrow ridge extending N.–S. across the township with the same name. While not such a conspicuous feature as Haystack Mountain at the southern end of the same ridge, it forms the most considerable prominence on the immediate bank of the Aroostook River along which route all the early travel lay, and hence was an important landmark to the first settlers. There is no common local usage as to the limits of Castle Hill, and in this report the term will be applied to the masses of andesite and volcanic clastics which lie between the Aroostook River and the "State Road" from Ashland to Presque Isle. It covers an area 2½ miles long varying in width from ½ to ¾ mile, and is partly in Castle Hill township and partly in Wade plantation. The wagon road crosses the hill at its southern end, where it rises little higher than the surrounding plain. The eastern side has a gentle slope, and is cut up into several low knobs by small streams, so that the ridge effect is not apparent. The west side is formed by Welt's brook and the Aroostook River, which at this point is forced by it to take the abrupt backward turn so noticeable on the map. Calcareous and arenaceous slates are exposed in the bed of the river, while a short distance back steep slopes and cliffs of lava and ash rise to a height of several hundred feet. The hill is densely wooded and in places swampy except at the southern end and along the east side. At these points the bare rocks are occasionally exposed and present a great variation in character. In one place heavy ledges of gray andesite are exposed, particularly on the knobs occupying the northwest and southeast corners of lot 31. Again in the woods east of the mouth of Welt's brook is an outcrop of black silicified tuff between slates. On the southeast corner of the hill are loose ash beds containing fossils, coarse and fine volcanic breccias, and pumiceous lava in quite fresh condition. Where the glaciers have planed off the old lavas and they have been protected from weathering, the outlines of bombs and pillows are plainly revealed, and when weathered these bombs are loosened and drop out as oval or egg-shaped bodies with amygdaloidal surface and denser interior, and lie about thickly strewing the fields. In one place there is a cistern-like depression some ten feet deep and thirty feet in diameter made in the solid andesite, while about it are piled close at hand a great number of very vesicular bombs and much glassy and brecciated ash. The whole appearance suggests a small blowhole made by a single explosion. The striking fact about all the volcanic accumulations in the Castle Hill region is their freshness and their unmistakable character.

Petrography.

Generally speaking, the andesites of this region belong to well-recognized varieties widely distributed over the earth and differ in no important particulars from the type rocks of their class. There are varieties found here, however, which are intermediate between andesites and trachytes and also occurrences with dacite facies. The exposures are numerous and easy of access and the specimens are no more altered in composition than if they were Tertiary lavas instead of Paleozoic.

Augite-Andesite—Macroscopic description.—The largest and best single exposure of andesite in this region is of this variety and forms the main mass of Edmund's Hill. It does not occur as a solid compact mass, but is broken by cleavage and shearing planes into large blocks on top, and into plates and slated material at the ends of the hill. This slated and seemingly bedded appearance, which is so unusual in an igneous rock, is the most marked peculiarity of the structure of the hill. In a few places the rock is seen to contain embedded angular pebbles of glass and baked siliceous material which stand out when it weathers; and in other places the rock presents a banded surface of gray and brown giving the appearance of bedding, but which prove on examination to be varying stages of decomposition along potential cleavages. With these exceptions the exposed rock has a uniform appearance, gray where weathered, black where fresh.

Andesites are so well known that an extended macroscopic description is unnecessary and will not be attempted. The hand specimen appears as a black, basaltic-looking rock, generally dense, with a stringy effect and sprinkled over with glassy feldspar 2^{mm} and less in length. The weathered surface is a layer of spongy, gray-brown material in which the pores are made by the decay of the larger feldspars. At the east end of the hill the rock is much lighter in color and numerous white feldspars give it a more porphyritic appearance.

Microscopic.—As with the hand specimen, so microscopic examination reveals the composition and structure expected of a typical andesite. Magnetite, apatite, pyroxene, plagioclase, and orthoclase are the original minerals present. The plagioclase crystals range in size from laths 2^{mm} in length down to the very fine ones in the groundmass, but the larger ones are not abundant and do not give the rock a porphyritic aspect. The plagioclase forming the crystals outside the groundmass was determined by Michel Lévy's method to be labradorite; but the measurements indicated two labradorites with the formulæ: Ab_3An_4 and Ab_5An_6. The larger feldspars show strongly marked zonal banding with occasionally as many as eight distinct zones, which decrease in basicity from the center outward, but with the original albite twinning running through the whole series. This albite twinning shows in nearly every feldspar lath with great distinctness, and twins on the pericline and manebach laws also occur. The carlsbad twins present are often with one-half dropped much below the other, and all the twinning is more or less along irregular ragged lines and with unsymmetrical development. None of the feldspars are entirely fresh, but are kaolinized along the cleavages and zonal boundaries, or entirely altered to kaolin and calcite except their outer borders. They also show irregular cracks other than cleavage along which strain has been relieved. Glass inclusions, arranged without order, are numerous and stand out prominently in the clearer parts of the feldspars. Orthoclase was not found outside the groundmass except as forming the wide outer rim of the zonally-built plagioclases.

The Pyroxenes are of both monoclinic and orthorhombic varieties. The monoclinic is an augite, light colored in thin section and having an average extinction on prism sections of 42°. The basal sections are quite fresh and show the cleavage parallel to the prism. The pinacoids are more developed than the prism faces and give the appearance of a square with truncated corners rather than the more common octagonal effect. The prism sections vary from stout forms to those five or six times as long as broad. In places many small pieces are arranged in parallel position and separated by alteration products in such a way as to suggest the presence of augite phenocrysts of which these fragments are the remnants. The orthorhombic pyroxenes are represented in the darkest colored rocks by a few basal and prism sections, but in the gray varieties it constitutes fully half of the pyroxenes present. It is very light colored, not at all pleochroic, and is at times partly eaten away and again occurs as parallel intergrowths with the augite. It seems to be a variety poor in iron, is optically +, and hence referred to enstatite. In the fresher rock specimens the cleavage cracks and borders of the enstatite often show the presence of a red-brown fibrous mineral. In the more weathered rocks this mineral assumes a prominent role. It is here found intergrown with augite and forming fibrous laths with parallel extinction. Its pleochroism is distinct with a = light brown, c = light green. The presence of this mineral in a slide seems to be in proportion to the absence of the orthorhombic pyroxene, and this fact together with its shape and optical properties point to bastite and make the supposition plausible that the red-brown mineral is the present representative of the original orthorhombic pyroxene. The magnetite is present in grains or dust aggregates, and the apatite occurs in needles, laths, and rounded sections within the feldspars.

The *groundmass* consists essentially of feldspar laths, long, narrow, with ragged outline and split ends, arranged with trachytic structure tending toward the hyalopilitic, and with flow phenomena developed in places. No close distinction can be drawn between the groundmass feldspars and those which rise slightly above it, as all sizes are represented grading up to the very largest ones present. Optical measurements on some of the freshest pieces in the groundmass proved them also to be labradorite, although orthoclase must also be present as demanded by the analysis. Besides the feldspars, augite grains are scattered abundantly throughout and small areas of brown glass, occasionally with bubbles, also occur. The whole slide is darkened by iron dust, both magnetite and limonite or göthite. The rock is, however, in a remarkably fresh state considering its age and position, and its character is unmistakable.

Analysis.—The analysis of this rock made by Dr. W. F. Hillebrand of the U. S. Geol. Survey is given in column I below and with it analyses (columns II–VI) of well known andesites from other localities are given for comparison.

From a study of the tables it becomes apparent that the Edmund's Hill rock presents no points of distinction from recognized types found elsewhere, and the tables could be greatly enlarged by the addition of closely similar analyses. The analysis in column VII requires some notice. The rock is described as a red andesite with "rather basic" feldspars and with calcite and magnetite present. The altered condition of the rock made accurate optical determination impossible. In discussing the analysis the writer says (l. c. p. 34), "In its mineralogical composition, this rock approaches the basaltic type but, as the analysis shows, is somewhat too acid. The olivine phenocrysts, moreover, are not very numerous and there

	I	II	III	IV	V	VI	VII
SiO_2	61·40	61·58	61·29	61·04	61·45	61·17	63·25
Al_2O_3	16·59	16·96	17·68	15·72	15·07	17·74	14·89
Fe_2O_3	2·13	1·75	6·03	5·03	4·46	1·78	6·54
FeO	3·05	2·85	·30	2·15	1·18	3·51	none
MgO	2·73	3·67	2·45	3·61	3·02	2·76	·82
CaO	6·17	6·28	5·61	5·34	5·37	5·90	·59
Na_2O	3·83	3·94	4·28	4·02	4·00	3·79	4·47
K_2O	1·34	1·28	1·38	2·66	1·22	1·71	4·78
$H_2O-105°$	·82	·24	·96	·58	1·23	·83	2 67
$H_2O+105°$	·88	1·06					
TiO_2	·79	·49	·65			·45	trace
ZrO_2	none						
Cr_2O_3	trace					none	
V_2O_3	·02						
NiO	trace						
MnO	·13	trace			none	·12	
BaO	·02	·03				·06	
SrO	trace ?	trace				·04	
Li_2O	trace	trace			·05	trace	
P_2O_5	·20	·22			trace	·14	·61
CO_2	none						·78
Cl	?						
Fl	?						
FeS_2	none				(SO_3 ·29)		loss ·53
	100·10	99·23	100·63	100·15	100·14	100·00	99·93

I. Andesite, Edmund's Hill, Aroostook Co., Maine. Analysis by W. F. Hillebrand.

II. Hornblende andesite, Mt. Shasta, Cal. Analysis by N. H. Stokes, Bul. U. S. Geol. Survey, 148, p. 190.

III. Hornblende dacite, Anzeion, Ægina. Analysis Dr. A. Röhrig, H. S. Washington, Jour. of Geol., vol. iii, p. 150.

IV. Pyroxene andesite, Peñon de Pitayo, United States of Columbia. Kuch: Geol. Studien in der Republik Colombia, Pt. I. Berlin, 1892.

V. Pyroxene andesite, Agate Creek, Yellowstone National Park. Analysis by Whitfield, U. S. Geol. Survey, Bul. 148, p. 134.

VI. Hypersthene andesite, Crater Peak (Lassen Peak Region). Analysis by W. F. Hillebrand. U. S. Geol. Survey, Bul. 148, p. 197.

VII. ? Andesite, Fox Islands, Maine. Analyses by E. W. Magruder and W. A. Jones in Johns Hopkins University Laboratory. G. O. Smith, Geol. of Fox Islands, Maine. Presented as a thesis, Johns Hopkins University, 1896.

is reason to regard this as simply an olivine-bearing phase of the andesite." The description is of an andesite, but there are discrepancies between the description and the analysis. No ferrous iron is present to form magnetite, and if the small amount of lime forms calcite, basic feldspars could not be produced. And even if the whole 0·59 per cent of lime were present as andesine or labradorite the amount is far too small for an andesite. According to the generally accepted usage among petrographers, a rock with such a high percentage of soda and potash with little lime and magnesia would be classed as a trachyte or more closely, an ægerine-trachyte.

Hornblende-andesite.—The largest single mass of this rock is Hobart's Hill, and the freshest and most typical specimens are from this hill and from the west bank of the Presque Isle near the northwest foot of the hill, where quarrying was attempted at one time. The hand specimen shows a very dark gray, almost black, rock, fine-grained, but with a somewhat porphyritic appearance caused by the occasional feldspar crystals which rise above the general groundmass and reflect light well from their glassy cleavage faces. Some few feldspar laths attain a length of 5–6^{mm}. The rock breaks out into tabular blocks along the cleavages and weathers to a brownish gray color.

Microscopic description.—In thin section the microscope reveals magnetite, apatite, titanite, rarely a zircon lath, possibly augite, hornblende, plagioclase, and orthoclase together with considerable secondary calcite. The feldspars range from 2^{mm} in length down to minute microlites. The larger feldspars are commonly converted to calcite, which while it indicates their basic character, also prevents their accurate determination. Those which could be measured by the Michel-Lévy method proved to be andesine with formula Ab_1An_1, hence more acid than the feldspars of the augite andesine. They contain glass inclusions, are zonally built with an occasional unaltered outer border, and are twinned according to the Carlsbad and albite laws but with very irregular intergrowths of the parts.

Hornblende is the only important ferro-magnesian mineral present and occurs, as the feldspars, both as large basal sections and long laths often with good crystal outline and also as shreds in the groundmass. The larger pieces are rarely in a good state of preservation, but occur with ragged edges and show resorption phenomena. The crystal is eaten into and part of the interior converted into magnetite with a few augite grains. Some crystals have been almost entirely replaced by calcite and magnetite, and others are represented by a ghost-like outline of magnetite dust. Commonly the hornblende is now changed to a green micaceous material, perhaps a variety of chlorite, with parallel extinction and a pleochroism, $\mathfrak{c}$ = white green, $\mathfrak{a}$ = brown green. At times the former crystal is striped across with alternating bands of green and white in the direction of the cleavage cracks. Some of the crystals classed as hornblende are so altered that it is impossible to say that they may not be augite.

The groundmass is formed of small, stringy, ragged feldspars and varies in different slides from trachytic or pilotaxitic, with possibly a little glass, to a type formerly quite glassy and showing devitrified areas with incipient micropoikilitic structure. The feldspar microlites could not be accurately determined, but their average extinction indicates a variety as acid as oligoclase-andesine, and if strict nomenclature were to be considered, the rock would be classed as a trachyte-andesite.

Andesites of Southern Mapleton.—These occur in several localities and are either identical with, or present only minor variations from, the Edmund's Hill and Hobart's Hill masses. The rock which outcrops in the road two miles east of Mapleton village has the most glassy groundmass of all the andesites, and its devitrified areas have the micropoikilitic structure the best developed. Two outcrops show a type much lighter in color with much secondary and some original quartz, giving the rock a dacite facies. The other sections examined are of the typical augite-andesite or hornblende-andesite of this region, and require no detailed description.

Andesites of Castle Hill—Macroscopic description.—The rocks at this place do not have the character of lavas which have formed thick flows, but suggest rather the surface of a flow and are commonly amygdaloidal, or even slightly brecciated and ashy, and associated with them is an abundance of true volcanic ash with lapilli. The rock exposed at the southeast base of the hill is striking in its field appearance. Black, rusty-looking, spheroidal or elliptical masses of lava, one to two feet in diameter, first attract the attention as they lie loosely strewn over the surface. The solid ledge itself is seen to be composed of these forms, which have their outlines well displayed by weathering. These sack-like or pillow-shaped masses are plainly amygdaloidal on the surface, but usually much denser in the interior and are cemented together by a coarse breccia of rough tabular, spheroidal, or irregular jagged fragments of glassy material and igneous rock of similar composition to the spheres. In some places, noticeably on McDonald's hill to the south of Castle Hill proper, this structure assumes the form of a conglomerate of small amygdaloidal spheres six inches and less in diameter, closely cemented together with angular pebbles of andesite and other igneous rocks. Similar structures have been described from California,* and from Scotland† and elsewhere. As noticed by Geikie, some basic lavas, e. g., the basalt at Acicastello in Sicily,‡ on flowing into water or a watery silt, assumes a remarkable spheroidal or pillow-shaped structure, "the spheroids being sometimes pressed into shapes like piles of sacks." This may be the explanation in the present case. Another interpretation is that the structure represents the ropy rolling surface at the front of a lava flow. On a fresh surface the rock is dark bluish-gray, uniform in texture or with a rare feldspar phenocryst. While this appears to be the most typical of the textures, it is usual to find vesicles now filled with calcite and fragments of volcanic debris large enough to constitute a conspicuous feature in the hand specimen. In weathering, the amygdaloidal parts go first and leave the more dense igneous and glassy pebbles exposed as a very rough surface.

Microscopic description.—Sections were cut from the densest material and also from that with macroscopic inclusions, and when examined with the microscope showed no difference except in size of vesicular areas and in method of alteration. Feldspar microlites make up the rock, parts of which are developed as areas of vesicular lava. The vesicles range in diameter from 2^{mm} to microscopic dots and are rudely oval in outline. The large ones are merely the larger part of a rounded area of vesicular glassy lava, containing a few feldspar threads like the body of the rock. Sometimes instead of one vesicle, filled with calcite, the same space will be occupied by a group of them, or the concave inner border of the large one may indicate its formation from several smaller ones. Some glassy oval areas occur with vesicles visible only under the highest powers. All these variations are doubtless caused by the fact that different sections of similar vesicular areas are exposed in the preparation of the slide. The only feldspar phenocryst seen in the sections is rounded in outline, has albite and pericline twinning, and is badly altered to calcite. Its extinction-angle indicates albite or andesine, and from the fact that phenocrysts are usually more basic than the components of the groundmass is referred to andesine. No ferro-magnesian mineral is present, but the numerous patches of chlorite and the fact that augite occurs in similar rock in the immediate neighborhood points to the former presence of pyroxene. Besides chlorite, there are present as secondary products calcite, a few epidote grains, and abundant iron ore. One slide is sprinkled full of stringy black iron ore in long threads or lines of partly connected dots which are arranged to form barbed arrows or network of fibers which cross at angles of 60° and 90°, thus imitating the sagenite structure of rutile.

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* Ransome: Bull. Depart. Geol. Univ. of California, vol. i, p. 106. Fairbanks: Bull. Depart. Geol. Univ. Cal., vol. ii, p 40.

† Geikie: Ancient Volcanoes of Gt. Britain, vol. i, p. 193.

‡ Johnston-Lavis: South Italian Volcanoes, p. 41.

The groundmass is of long, stringy, narrow, frayed out microlites of feldspar with trachytic structure. Measurements of many laths gave practically a parallel extinction, thus indicating oligoclase. Expansion structure is developed where the vesicular areas are large enough to affect the orientation of the minute laths constituting the main body of the rock.

Andesite Ash Beds.—Beds of volcanic ash of an andesite character are represented in the region covered by this report. They are particularly abundant about Castle Hill and will be discussed in another place.

ART. XLIV.—*On a new mode of occurrence of Ruby in North Carolina;*[*] by J. W. JUDD and W. E. HIDDEN. With Crystallographic Notes by J. H. PRATT.

PARTS of the State of North Carolina, with adjoining areas in South Carolina and Georgia, have long been known to mineralogists and geologists as among the most interesting of corundum localities; and the researches of the late Dr. Genth, Col. Joseph Willcox, Mr. J. Volney Lewis and many other authors have done much to make clear the mode of occurrence and associations of corundum in this area and in the great corundiferous belt stretching along the line of the Appalachian crystalline area from Alabama in the south to Maine in the north. Quite recently Dr. J. H. Pratt has published a very interesting and admirable discussion of "The origin of the Corundum associated with the Peridotites of North Carolina."[†]

But of the existence in any part of this area, or indeed in any part of the continent of America, of the red transparent variety of the mineral, to which the term Ruby is properly restricted, there appears to have been no knowledge till about 15 years ago (1884). Nor has there been, as yet, any notice published of the discovery in any scientific journal or magazine, unless we except the brief mention made in the Annual Statistical volume entitled Mineral Resources of the United States, published under the auspices of the U. S. Geological Survey.[‡]

Some few additional notes upon this interesting occurrence have been published, including press notices, but nothing of a strictly scientific character. We may state that one of us has during the past five years frequently visited the scene of this discovery, and that from time to time we have conjointly examined many of the cut specimens and natural crystals of the rubies from the Cowee district of North Carolina, and that in our opinion their beauty and color appear to be in no way inferior to those from the Mogok district of Burma.

As the material in which these rubies were found appeared so strikingly similar to the alluvium and gravel in which the Burma rubies are obtained, it at one time seemed highly probable that when the thick masses of superficial and detrital material could be sunk through, the rock in which the rubies would be found *in situ* would prove to be a limestone like that of Burma. This expectation was strengthened by the finding in the gravels of corundum crystals of similar form, with almost precisely the same association of minerals as occurs in Burma.

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[*] From advance sheets of the Mineralogical Magazine and Journal of the Mineralogical Society, vol. xii, No. 56 (October, 1899).

[†] This Journal, IV, vol. vi, 1898, p. 49.

[‡] 15th Annual Report, 1893–94, U. S. Geol. Survey. volume on Mineral Resources of the United States, Washington, 1894, p. 693; ibid., 16th Annual Report, part iv, p. 599; ibid., 17th Annual Report, part iii, p. 905.

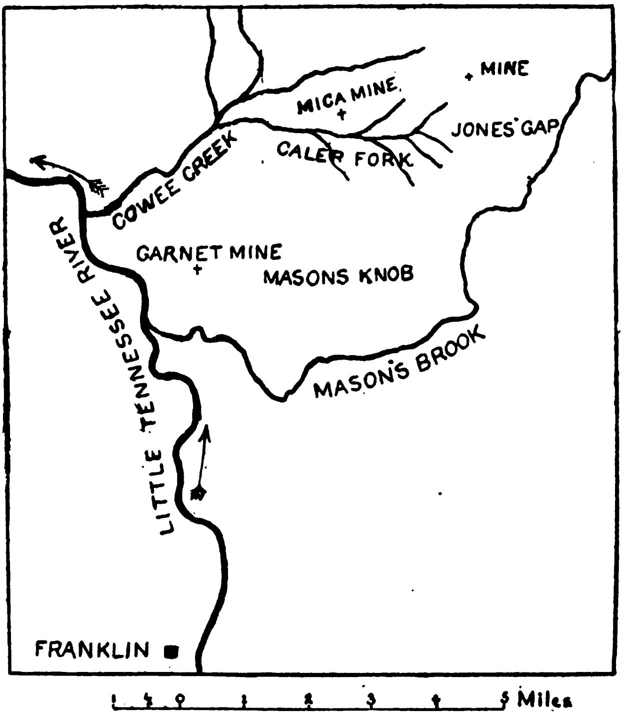

FIG. 1. **Sketch map of the district in which Ruby and Rhodolite are found.**

The district in which these interesting discoveries have been made is situated in the State of North Carolina and in the County of Macon, rather more than 20 miles from the borders of Georgia. Some five or six miles below the town of Franklin the Little Tennessee River receives on its right or eastern side two affluents, the Cowee Creek with its tributary the Caler Fork, and the Mason Branch. It is the tract between these two brooks, some 10 square miles in area, which has proved to be of such exceptional mineralogical interest, and has yielded a very large number of remarkable species and varieties of minerals.

The bottoms of the valleys of this mountain district are about 2,500 feet above the sea-level, and the various hills ("knobs") in and immediately around it rise to the height of from 3,000 to 3,500 feet; but at no great distance to the west there occurs much higher ground (the Nantahaleh Mountains) up to 5,000 and 5,500 feet.

In 1896 the district was visited and examined by Mr. C. Barrington Brown, who had made the examination for the British Government of the well-known ruby district of Mogok in Burma. He found that the country was one of gneissose rocks, the gneiss often containing garnets and corundum,* not of gem quality, and that this mass of gneissose rocks is probably traversed, like that of Burma, by great dikes of pegmatite and more basic rocks, for blocks of these materials are abundantly scattered through the gravels of the district.

Garnets are so abundant in some of the rocks of the district that mines have been opened to work the rocks for abrasive materials. In some of the pegmatites the crystals of muscovite are so well developed that several "mica mines" have been opened. There are other mines which have been worked for copper with some prospects of success; while, as we shall see in the sequel, gold, monazite, and sperrylite (the rare arsenide of platinum) have been obtained in the alluvial deposits which are so extensively present in this region.

Although only a few miles away from Corundum Hill, Buck Creek, Ellijay, and other famous corundum localities, where, as shown by Lewis, Pratt, and other authors, corundum is found in the intrusive dunites, near their junction with the crystalline schists of the district, *no* olivine rocks, or serpentines derived from them, have been found in the immediate neighborhood of the new ruby locality.

Neither have limestone rocks been found in close proximity to the alluvia containing these fine rubies. In fact, the nearest point at which any limestone bands have been found is about eight miles away. Here the bands consist of a "calciphyre," not unlike some of those found in Burma, and, like them, containing many silicates, such as wollastonite, scapolite, pyroxenes, hornblendes, biotite, etc., with graphite, pyrrhotite, and many other minerals.

When the alluvium and the gravels below them (the latter being from 2 to 10 feet in thickness) are penetrated, they are often found to rest on a soft rock known to American petrologists as "saprolite," which is the result of the weathering in place of basic silicate rocks. This "saprolitic" rock can often be pierced to considerable depths, without the undecomposed rocks from which it has been derived being reached.

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* The corundum in these gneissose rocks usually occurs in long hexagonal prisms with basal planes, but no other forms, and the mineral nearly always exhibits purplish tints.

Washing and microscopic examination of the saprolitic material shows that it is largely made up of scales of various hydrous silicates, among which damourite and other hydrous micas, with margarites and other clintonites, are very conspicuous. The unaltered minerals present consist of fibrolite, staurolite, and some other silicates, with menaccanite, rutile, monazite, spinel, and considerable quantities of garnet (including the rhodolite variety) and corundum (of various shapes and tints), and minute quantities of gold and sperrylite.

The trial shafts and gravel-washing operations which have been undertaken in this district, with a view to discover the extent and nature of the valuable minerals, have shown that at depths of 35 feet and upwards the saprolitic rock includes fragments, and is seen to pass into various basic rocks. These include hornblende-eclogite (garnet-amphibolite of some authors), amphibolite, and a basic hornblendic gneiss containing labradorite and perhaps anorthite. The full description of these rocks is deferred until the exploration now going on shall have more fully displayed their relations in the field, and have enabled more satisfactory and less altered specimens to be obtained. It is as yet uncertain whether these rocks occur as dikes or as alternating interfoliated masses in the crystalline series.

The great band of basic and garnet-bearing rocks, in the decomposed materials derived from which are found the rubies, is traversed by a remarkable series of slickensides. Four parallel slides have been exposed at one place in the workings, the direction being generally N. 75° E. Continuous slickensides of 70 feet in length, and of unknown depth, can be seen, and, with some interruptions, they can be traced for several hundreds of feet east and west. It is probably the breaking up of these rock-masses by faulting, leading to the ready influx of water (which so readily attacks the basic silicates of which the rock is composed), that has led to their reduction to the saprolitic condition.

Scattered through the saprolitic material are nuclei of eclogite and amphibolite, which have to some extent escaped disintegration, and in the center of the mass lenticles of pure hornblende rock are found. In one place one of these lenticles of hornblende rock is nearly a rod in width, and in nearly all cases the saprolite adjoining these lenticles of hornblende rock is seen to contain, very abundantly, either corundum or more commonly the pseudomorphs after corundum.

The corundum occurring in these rocks varies in color from ruby-red through various shades of pink to white and nearly colorless varieties. Many of the red crystals exhibit the beautiful so-called pigeon's-blood tint, which is so much admired in the gems from Burma, and the colors seen in the Cowee Creek stones with the dichroscope are almost identical with those exhibited by the stones from Burma. As at Mogok, Sagyin, and other Burmese localities, the rubies of very fine tint are mingled with others of lighter or darker shades, and with varieties which exhibit more or less of a purplish tint mingled with the red.

The Cowee Creek rubies very frequently contain inclusions of various kinds. Sometimes these are extremely minute ("silk" of jewellers), and give rise to a cloudiness ("sheen") in the polished gems; at other times minute reniform masses of clear red rutile and black menaccanite occur, and mar their beauty. The included crystals of garnet, to be hereafter more particularly noticed, do not greatly destroy the transparency or impair the fine character of the stones. Some specimens have been found, however, from which gems of fair size could be cut, quite free from inclusions and of fine color and transparency.

The clearest crystals of the Cowee Creek rubies nearly always show the tabular habit which Lagorio regards as characteristic of the varieties of corundum that have separated from an igneous magma. Indeed, so common is this form, that any long prismatic crystals found with them may be suspected of having been derived from the surrounding gneisses, in which such forms occur sometimes abundantly. The most common combination of forms is that shown in the accompanying drawing, which has been made by Professor S. L. Penfield, of the Sheffield Scientific School, Yale University.

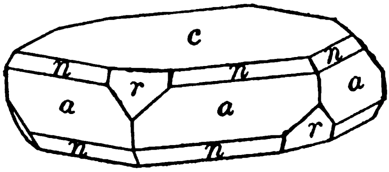

Fig. 2. Common form of Corundum Crystals at Cowee Creek.

In an appendix to this paper Dr. Pratt has drawn and described some of the chief types of corundum crystals obtained in the Cowee district, and it will be found interesting to compare these with the combinations of forms which the same author has described as occurring at Yogo Gulch, Montana,* and which Dr. Max Bauer has described from Burma.†

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* This Journal, IV, vol. iv, 1897, pp. 424–428.

† Neues Jahrb. für Min., etc., 1896, Bd. II. pp. 197–238.

The corundum crystals, whether ruby-red or pink in color, occur in "nests" and "bands," and also in what appear to have once been empty spaces in the rocks, either amphibolite, or eclogite, or hornblendic gneiss. The spaces, when the corundum is pale-colored, appear to have been filled up with felspathic material; but when the corundum is of ruby-red color, the surrounding space is filled up with chloritic material.

Corundum is not, however, confined wholly to these bands, which were once druse-like cavities in the rock, but it often happens that the mineral, sometimes red and transparent, is found in the midst of the rock.

One respect in which the corundum of Cowee Creek resembles that of Burma is in the readiness with which it seems to have undergone pseudomorphous change by hydration followed by combination of the resulting diaspore with surrounding silicates. The pseudomorphous material often retains the shape and occupies the place where crystals of corundum were originally firmly embedded in the hard matrix. Often only a thin flake of corundum remains in the midst of a mass of alteration products to tell the character and color of what was once a large crystal.

It is surprising to see the positive evidence of the former existence of hundreds of pounds weight of ruby and other varieties of corundum, where, to-day, only a few ounces of fragments or flakes remain.

The most notable of the minerals associated with the rubies and other forms of corundum at Cowee Creek is garnet, and this garnet is remarkable for its color and beauty as a gem-stone. The color is unlike that either of pyrope or almandine, and lacks that depth and intensity which usually makes garnets such dark-looking stones, especially by artificial light. These garnets, on the contrary, have a peculiar and very beautiful tint, combined with a transparency and brilliancy which is more striking in artificial light than in ordinary daylight. From the resemblance of its color (a pale rosy tint inclining to purple) to that of certain roses and rhododendrons, this variety of garnet has received the name of "rhodolite."*

The rhodolite usually occurs in water-worn fragments, mixed with corundum and the other minerals found in the "saprolitic" rock and in the gravels of the district. Only minute crystals, occurring as inclusions, have as yet been found, and these are sometimes rhombic-dodecahedrons and at other times trapezohedrons (icositetrahedrons). The garnets show the same tendency to alteration as the corundum, and pseudomorphs of the mineral abound, as is the case in Burma.

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* The rhodolite of the Cowee Creek and Mason's Branch district has been recently carefully studied by Dr. Pratt in conjunction with one of us.

The association of rubies and rhodolite in this district is not only proved by their constant occurrence together in the saprolitic material and in the gravels, but we found indisputable evidence that the garnets have crystallized first and that the corundum has solidified afterwards and has enclosed the garnets partially or entirely in its crystals. Some of the ruby crystals bear impressions, of which a mould can be taken in wax, and these impressions give with a goniometer the angles of the rhombic-dodecahedron or the trapezohedron. In some cases clear crystals of ruby corundum have been broken open, and minute garnets actually taken out of the middle of them. In other cases fractured surfaces of the basic rocks show corundum surrounding and enclosing garnet crystals, while in other cases cut gems of ruby can be seen to have in their midst a garnet crystal.

So far as our experience goes, this enclosure of garnet by corundum is peculiar to this special Cowee district, and serves to distinguish the corundum found in it from that occurring in any of the tracts where the mineral occurs in peridotites (dunite, etc.), or at the junction of peridotites with the crystalline schists.

This remarkable association of garnet and corundum is well illustrated by a drawing (fig. 3) made upon the spot by one of us from a specimen.

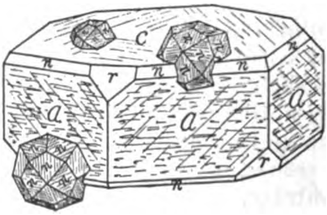

Fig. 3. Corundum enclosing Crystals of Garnet.

Specimens are occasionally found in the district which appear to be pseudomorphs of quartz after dodecahedral garnets.

Spinel, which is so constantly associated with the corundum (ruby) of Burma, is rare in the American locality. The fine red spinels, so similar in tint to the rubies themselves, and so conspicuous in the Burma localities, appear to be entirely wanting in the North Carolina area. Three varieties of spinel, namely, picotite, gahnite, and chromite (the last being rare), have been found both in the alluvial deposits and *in situ* in the basic rocks.

Of minerals specially characteristic of materials formed by contact metamorphism, the following have been found: Sillimanite (fibrolite), cyanite, staurolite (often very clear and gem-like in character), and cordierite or iolite (colorless and without dichroism).

The chief ferro-magnesian silicates are hornblende (a variety rich in soda) and bronzite (in clear transparent masses suitable for gems).

Among the accompanying minerals are: zircon (with the variety cyrtolite), monazite (the macroscopic brown and green varieties appear to be rare, but a minute brilliant yellow granular variety with only 0·03 per cent of thoria abounds), rutile and menaccanite.

Among metallic minerals the chief are pyrite, chalcopyrite, nickeliferous pyrrhotite, blende, sperrylite, and gold.*

Conclusions.

Corundum has now been shown to occur in North Carolina and the adjoining States in three different forms:

(1) In the ordinary crystalline schists of the district, long prismatic crystals, usually of gray, pink and blue tints, occur.

(2) In the peridotites (dunites, etc.), intrusive in the crystalline schists, and especially in and near the zones of contact, crystals, some of very great size and of great variety of color, but seldom or never clear and translucent, are found.

(3) In certain garnet-bearing basic rocks at Cowee Creek, small tabular and short prismatic crystals are abundant, and these very frequently exhibit the transparency and color of the true ruby.

Dr. Pratt, in his recent discussion on the second of these modes of occurrence of corundum, has shown grounds for concluding that the alumina of the corundum was in these cases originally dissolved in the fused basic magma of the peridotites, and that crystals of corundum separated from that magma in the manner which has been illustrated by the interesting experiments of Morozewicz.†

The tabular form of the crystals of corundum has been shown by Lagorio‡ in his well-known memoir on the subject to be characteristic of corundum found in igneous rocks. And this conclusion has been supported by the researches of Prof. L. V. Pirsson and Dr. Pratt.§

If we compare the forms figured by Dr. Pratt in the appendix to this paper with those described by him from Yogo Gulch, the resemblance will be seen to be very striking. But it may at first sight appear that it is impossible to ascribe an igneous origin to corundum enclosing a mineral with so much lower a fusing point as that of garnet.

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* For fuller details concerning these accompanying minerals with analyses consult a paper "On the Associated Minerals of Rhodolite," by W. E. Hidden and J. H. Pratt, this Journal, IV, vol. vi, 1898, pp. 463–468.

† Zeitschr. Kryst., vol. xxiv, 1895, p 281, and Tscherm. Min. und Petr. Mitt. vol. xviii, 1898, pp. 1–90, 105–240.

‡ Zeitschr. Kryst., vol. xxiv, 1895, p. 285.

§ "Corundum-bearing Rock from Yogo Gulch, Montana," by L. V. Pirsson, this Journal, IV, vol. iv, 1897, p. 421; "Crystallography of the Montana Sapphires," by J. H. Pratt, ibid., p. 424.

A little consideration will, however, show that this objection has little validity. The temperature at which alumina is dissolved in a mixture of silicates has no necessary connection with the fusing point of alumina itself. That the magma from which these basic rocks consolidated was fluid at a temperature lower than the fusing point of the garnets, or at all events that the rock was in a state of aqueo-igneous fusion at a lower temperature, is evidenced by the condition of the beautifully crystallized garnets scattered through the basic rocks. At such temperatures, according to the experiments of Morozewicz, alumina may be largely dissolved in the basic fluid magma, and may slowly crystallize out from it. In this way we may conceive of the garnets being enclosed in a later formed corundum.

There are many points of resemblance between the association of minerals and the forms of crystallization of the Cowee Creek rubies and those of Burma. This will become apparent if we compare the figures now published with those given by Prof. Max Bauer of the Burma rubies.*

In considering the association of minerals described by Prof. Max Bauer in his paper, it should be remembered that the material on which that author worked came almost entirely from Sagyin, while those described by Mr. Barrington Brown and one of us were derived from the Mogok district, nearly 60 miles away. There is reason for concluding that the association of minerals in these two districts of Burma present some interesting points of difference.

Although, at first sight, the matrix of the Burma rubies (a crystalline limestone) may seem so different from that of the rubies of Cowee Creek (an amphibolite with garnets, and sometimes with a basic feldspar) yet a connection may still be shown to exist between the two cases. One of us has brought forward evidence to show† that the limestone of Burma has been formed by the slow alteration of a lime feldspar. Whether the corundum pre-existed in the highly-basic felspathic rock, however, or was formed at a later stage, there is no positive evidence to show. But the idea of its existence in the silicate rock originally is supported by the wonderfully corroded state of the corundum crystals.

The magma giving rise to pyroxene gneisses and granulites of Burma may not have differed greatly in composition from that giving rise to the amphibolites, eclogites, and basic gneiss of North Carolina; and, in either case, corundum may have been formed by the separation of dissolved alumina. The great promise which is held out by the fine color and quality of many of the ruby crystals from this new locality would seem to warrant a continuance of the prospecting work lately inaugurated there, and it is to be hoped that the interesting problem of *the true origin of these rubies* may be definitely settled when the explorations on Cowee-Creek shall have furnished fuller data and more conclusive evidence concerning the primary condition of the associated minerals and the nature and relations of the rocks of the district.

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* Neues Jahrb. Min., etc, 1896, Bd. ii, Taf. vii.

† Phil. Trans., vol. clxxxviiA, 1896, pp. 151–228.

On the Crystallography of the Rubies from Macon County, North Carolina; by J. H. Pratt.

The ruby crystals from the Cowee Valley, Macon County, North Carolina, show a very wide variation in their development. Although many of the crystals are so striated that no crystallographic measurements were possible on the reflecting goniometer, the faces were readily identified by means of the contact goniometer. On some of the crystals the faces were bright and smooth, making them well adapted for measurement on the reflecting goniometer. The following references are to the figures on p. 380.

Among the crystals examined there were two common habits noticed, one, as shown in figs. 1 and 2, which is a combination of the base $c(0001)$ and the unit rhombohedron $(10\bar{1}1)$; the other, represented by figs. 3 to 6, where the prism $a(11\bar{2}0)$ is very prominently developed. The rhombohedral crystals vary from those where the base is largely developed, having a diameter of 12^{mm}, while the rhombohedron is only $1{\cdot}5^{\text{mm}}$, to some (fig. 1) which have the base and rhombohedron more equally developed. The majority of these crystals have, however, the base more largely developed, thus giving the crystals a flat tabular appearance. This rhombohedral development is very similar to that of the sapphires from Yogo Gulch, Montana, described by the author.*

On some of the prismatic crystals the prism reaches a length of nearly 15^{mm} in the direction of the c-axis, and has the rhombohedron but slightly developed (fig. 3), while on others the prism is very short and the rhombohedron sometimes is wanting, as represented in figs. 4 and 5.

Another habit of these crystals is shown in figs. 7 and 8. There the pyramid $n(22\bar{4}3)$ is well developed. This face was identified by means of the contact goniometer, the measurements approximating closely to the calculated angles. The usual form of these crystals is shown in fig. 7, where the faces *c*(0001), *a*(11$\bar{2}$0), *r*(10$\bar{1}$1) and *n*(22$\bar{4}$3) are nearly equally developed. On some of the crystals the prism is very prominent, being 8^{mm} in length in the direction of the *c*-axis, while the pyramid is only $1{\cdot}5^{mm}$. On others the pyramid is only very

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* This Journal, vol. iv, 1897, p. 424.

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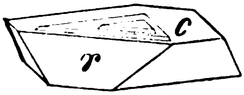

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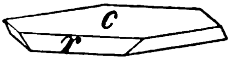

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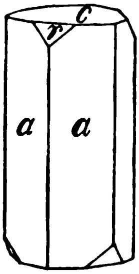

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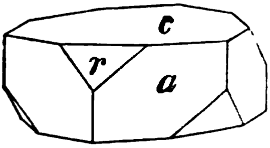

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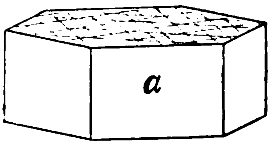

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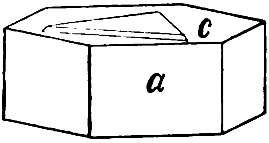

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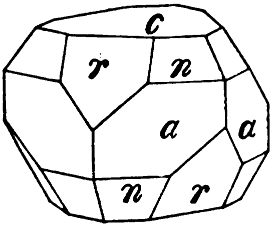

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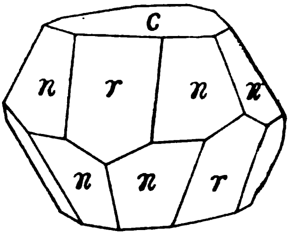

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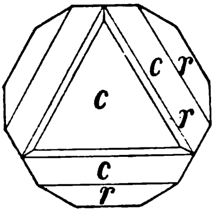

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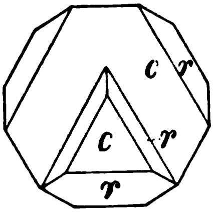

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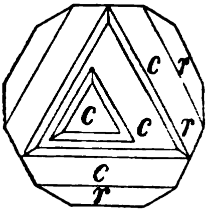

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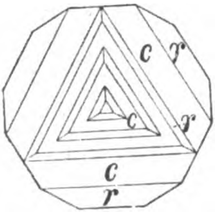

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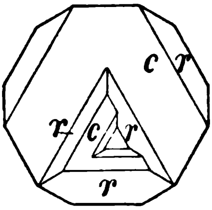

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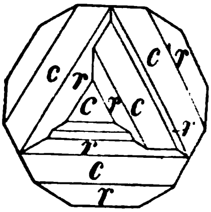

slightly developed. A few crystals were examined which showed only the presence of the base, the rhombohedron and the pyramid, as represented in fig. 8. The crystals, measuring up to 7^{mm} in diameter, were doubly terminated and nearly perfect in their development.

The crystals represented by fig. 7 are similar to those described by Max Bauer* from the Burma district, and are almost identical in form with a sapphire crystal figured by the author, from Emerald Bar, Cañon Ferry, Magher County, Montana.

Although both the basal and rhombohedral planes are very often striated, it is only on the basal planes that these are sharp and distinct and can be measured. The striations are parallel to the three intersections of the base c with the rhombohedron r, as shown in fig. 5.

A very common development that was noticed in nearly all the flat rhombohedral crystals, and on many of the prismatic crystals, is a repeated growth on the basal plane of the rhombohedron $r(10\bar{1}1)$ and the base $c(0001)$, as represented in figs. 1 and 6.

To better illustrate the variation in these growths, a series of figures (9 to 14) have been drawn in basal projection. In figs. 9 and 10, which represent the more common development of these repeated growths, there is but one secondary rhombohedron and base, which sometimes has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal. Figs. 11 and 12 represent repeated growths, the faces of which are separate and distinct from each other and from the faces of the main crystal. In the crystals represented by fig. 12, when the secondary growths are but slightly developed the basal plane of the crystal has the appearance of being striated with triangular markings. In figs. 13 and 14 there are represented a series of growths where a number of the rhombohedral faces coincide.

Some of the pyramidal crystals (figs. 7 and 8) also showed the development of the secondary growth of rhombohedron and base.

The thickness of the rhombohedron of the secondary growth varies from those that are so thin that they appear like striations to some that are 2^{mm} thick.

This same style of development has been described by Bauer† as occurring in the Burma rubies, and it has also been described by the author‡ as occurring on the Montana sapphires.

A few crystals were observed on which there was a secondary growth parallel to the prism $(11\bar{2}0)$.

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* Neues Jahrb Min., 1896, ii, 197.

† Loc. cit, p. 209.

‡ This Journal, vol. iv, 1897, p. 424.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Solidification of Hydrogen.*—Toward the end of 1898, as soon as Dewar had obtained two or three hundred cubic centimeters of liquid hydrogen, he attempted its solidification by boiling it under reduced pressure; but without result, no solid hydrogen being produced, even when the ebullition was effected under a pressure as low as ten millimeters. Subsequently he observed that a trifling leakage of air, such as it was almost impossible to prevent at this low temperature, produced, when the pressure was reduced below 60^{mm} a remarkable effect, causing a sudden solidification in the form of a gelatinous froth. At first he thought this was a sponge of solid air containing liquid hydrogen. But as it evaporated completely at this low pressure without leaving more than a trace of solid air, he concluded that it must be solid hydrogen. In confirmation of this view, he found that on increasing the pressure, and consequently the temperature, the solid melted when the pressure attained about 55^{mm}. Using a graduated tube attached to a closed balloon of about a liter capacity filled with pure hydrogen gas, he found that when this tube was immersed in boiling hydrogen, liquid hydrogen accumulated in it till the outside pressure reached 30 or 40^{mm} and the outside liquid became a solid froth. On inverting the apparatus, no flow could be observed along the tube; and in a strong light, the material in the lower part of this tube could be seen as a transparent ice. This solid hydrogen melted at a pressure of 55^{mm}. The temperature of fusion, determined with a hydrogen thermometer, was found to be about 16° absolute, under a pressure of 35^{mm}, theory indicating 16·7°. So that the practical limit of temperature which can be reached by the evaporation of solid hydrogen is 14° or 15° absolute. It is to be noted that the critical temperature of hydrogen being 30° to 32° absolute, its fusing point is one-half of this, i. e., 16°. The frothy appearance of the solid, as ordinarily produced, is due to the low density of the liquid and its rapid evaporation. These results would seem to destroy the hypothesis of the metallic character of hydrogen and to require its classification among the non-metallic elements.—*C. R.*, cxxix, 451–454, September, 1899. G. F. B.

2. *On Hydrazoic acid and its salts.*—Further researches have been made by Curtius and Rissom upon hydrazoic acid (HN_3) and its salts. The acid itself was prepared by distilling with sulphuric acid the lead nitride which is obtained as a by-product in the preparation of ammonium nitride. The aqueous solution thus obtained is quite permanent even on heating; but on boiling with strong acids it is decomposed with the evolution of gas. The ammonium nitride (NH_4N_3) is the most interesting of the

salts described. It is very volatile and explodes readily with great violence. But notwithstanding this the authors succeeded in determining its vapor density. The other salts arrange themselves according to their solubilities between the chloride and the bromide. In aqueous solution they behave as would be expected from the feebleness of the free acid. In the case of weaker bases, particularly alumina and iron oxide, strong hydrolysis takes place; so that in experiments made to form aluminum salts by double decomposition, alumina is precipitated. The non-dissociated part of the iron salts is colored deep red, like the acetates; but this substance is rapidly decomposed with the deposition of iron oxide.—*J. pr. Ch.*, lviii, 216-309, 1898; *Zeitschr. Phys. Chem.*, xxix, 174, May, 1899. G. F. B.

3. *On Argon and its Combinations.*—The earlier investigations of **Berthelot** to determine the possibility of causing argon to enter into combination with other bodies, have now been repeated under improved conditions. The argon was obtained from Ramsay, and after purification amounted to 455^{cc}. As in the previous experiments the argon, mixed with the substance to be acted upon, in either the gaseous, the liquid or the solid state, was placed in a silent discharge tube and submitted to the action of the electric spark from an induction coil giving discharges of 6 or 8^{mm}. Only from 5 to 10^{cc} of argon was used in each experiment, the substance added being gaseous, liquid or solid at pleasure. The first experiments were made with bodies of the fatty series, such as ethylene, aldehyde, acetone, petroleum ether, propionitrile and amylamine. No absorption of argon was observable. In the second set of experiments, bodies of the benzene series were tested, such as benzene, toluene, phenol, aniline and benzonitrile. A characteristic absorption of argon was observed, accompanied with a greenish luminescence visible in full daylight, and giving in its spectrum the lines of argon, of mercury, of carbon and of hydrogen; it being especially bright with benzene, toluene, benzonitrile and anisol. The author regards this result as due to the formation of a special substance phenylmercurargon, having only a very small vapor pressure. The action is in marked contrast with that on the fatty series. In a third set of experiments, cyclic compounds such as furfurol, thiophene, pyrrol and pyridine, were employed. The absorption of argon was much less, in some cases not even perceptible, and the light was feeble. Special experiments were then made with benzene and with carbon disulphide. In the case of benzene, the absorption of argon varied from 3 per cent. to 14 per cent, depending upon the relative amount of the two substances present and the time of exposure, the last result being obtained with equal volumes of argon and liquid benzene, the latter therefore in large excess. Benzene was found to dissolve 18 per cent of its volume of argon, carbon disulphide 6 per cent. The compound formed by argon with carbon disulphide is reddish in color and is solid. The absorption varied from 6 per cent. after six hours, to 7 after twenty

hours. By increasing the current pressure and so the temperature, the absorption was diminished. When hydrogen was added to the mixture, 10 per cent of argon was absorbed in 24 hours, all the hydrogen having disappeared. When benzene was thus added, the absorption was 9 per cent. It hence appears that to fix a molecule of argon (A_2) 34 molecules of carbon disulphide are required $(CS_2)_{34}$. In all cases a solid amorphous, reddish polymerized substance is formed; the polymerization of the bisulphide and the combination of hydrogen, of nitrogen or of argon proceeding simultaneously. The results obtained lead the author to suspect the existence of metallic argonides in those minerals which evolve argon under the action of acids, or even of hydrogen argonide. In a subsequent communication Berthelot gives the results of his experiments on the action of the electric discharge on argon mixed in one case with mercury-dimethyl, and in the other with mercury-diphenyl. No absorption took place in the first case, while in the second, owing to the production of phenylmercurargon, 6·5 per cent of argon was absorbed and the green luminescence was produced.—*C. R.*, cxxix, 71–84, 378–9, July, August, 1899. G. F. B.

4. *On Mercury in the Colloidal Condition.*—By reducing mercurous nitrate with stannous nitrate, adding ammonium citrate solution and filtering through an earthenware filter, LOTTERMOSER has succeeded in preparing colloidal mercury, which after drying is obtained in the form of brilliant silver-like masses which dissolve in water giving a dark brown solution. If this colloidal mercury is treated with dilute chlorine water, mercurous chloride is obtained, also in the colloidal state. In the same way the bromide and the iodide can be procured as colloids. The colloidal iodide appears as a deep red solution from which the iodide is rapidly deposited.—*J. pr. Ch.*, lvii, 484–487, 1898; *Zeitschr. Phys. Chem.*, xxix, 174, May, 1899. G. F. B.

5. *On Lithium-ammonium and Calcium-ammonium and the Amides of these Metals.*—It has been observed by MOISSAN that, like potassium and sodium, lithium and calcium dissolve in liquid ammonia with a blue color. But while the $NaNH_3$ decomposes at $-20°$ and KNH_3 at $-2°$, into metal and ammonia, the lithium and calcium compounds are permanent at the ordinary pressure and temperature, the $LiNH_3$ remaining unchanged up to $+70°$ and the $CaNH_3$ up to $+20°$; these compounds evolving so much heat in their formation that in the case of the lithium this metal is fused. On spontaneous evaporation as much ammonia becomes solid as corresponds to the formula $Li(NH_3)_2$. About 70°, there is formed crystallized $Li(NH_2)$; but by diminishing the pressure, this compound decomposes into metallic lithium and ammonia. Calcium ammonium corresponds to the formula $Ca(NH_3)_4$. Both lithium and calcium ammonium ignite spontaneously in the air. When instead of liquid ammonia, methylamine is brought in contact with lithium at $-20°$, a blue liquid is formed haviag approximately the composition $Li(NH_2CH_3)_2$. On evaporation in vacuo,

metallic lithium remains besides a blue crystalline compound $Li(NH_2CH_3)$ or lithium monomethylammonium, the NH_2CH_3 pressure being less than one atmosphere.—*C. R.*, cxxvii, 685–693, 1898; *ib.*, cxxviii, 26–30, 1899; *Zeitschr. Phys. Chem.*, xxix, 738, 747, September, 1899. G. F. B.

6. *On the Action of Potassammonium and of Sodammonium on Sulphur, Selenium and Tellurium.*—The action of the metallic ammoniums upon sulphur, selenium and tellurium has been studied by Hugot. The apparatus used consisted of two large parallel tubes of glass united by a smaller tube containing glass wool. The metal and the metalloid are placed in one branch of the tube, previously filled with ammonia gas. The two branches are then sealed and connected with a reservoir containing the liquid ammonia, which collects in one of these branches. The alkali-ammonium dissolves in the excess of liquid giving a reddish-brown solution, which reacts upon the sulphur, selenium or tellurium present, giving rise to a white powder insoluble in the liquid (if the metalloid is present in excess) and which has the composition Na_2S, Na_2Se, or Na_2Te, formed with sodium or K_2S, K_2Se or K_2Te, when potassium is used. They are soluble in water free of air and give a colorless solution. When, however, the metalloid is in excess, the mono-compound which is first formed dissolves, the liquid becomes brown or violet and very limpid. On evaporating it at —25°, with subsequent lowering of pressure, the excess of ammonia is removed and a brown crystalline mass is left having the composition K_2Se_4 or Na_2Se_4 for selenium and similar formulas for sulphur and tellurium. These substances are all crystalline, are soluble in water but not soluble in liquid ammonia. They absorb ammonia gas.—*C. R.*, cxxix, 299–302; 388–390, July, August, 1899. G. F. B.

7. *A Short History of the Progress of Scientific Chemistry in our own times;* by William A. Tilden, F.R.S., Professor of Chemistry in the Royal College of Science, London. 8vo, pp. x, 276. New York, 1899 (Longmans, Green & Co.).—This excellent little book of Professor Tilden's had its origin in a course of lectures to working men such as the professors in the Royal School of Mines and the Royal College of Science have delivered annually for the last five and thirty years. Among the subjects treated in its ten chapters are Matter and Energy, the Chemical Elements, Standardization and Classification of Atomic Weights, Origin of the ideas of Valency, Synthetical and Stereo-Chemistry and the Liquefaction of Gases. The facts have been carefully selected and are attractively presented. The book will be of great service to the chemical student as a valuable résumé of the recent progress of Chemical Science. G. F. B.

8. *Refraction of the X-rays.*—A renewed interest has been taken in this subject. It seemed to H. Haga and C. H. Wind, that the investigations of Fomm, Wied. Ann., lix, p. 350, 1896, appeared to open a way for the determination of a possible refraction. It was shown by P. G. Tiddens, Beibl., xxi, p. 603, 1897, that the Fomm

bands were not produced by refraction. Haga and Wind set themselves to determine what causes the Fomm bands and whether there are refraction phenomena in the case of the X-rays. The Fomm bands or lines are maxima produced by a difference of illumination on a surface lighted through a slit, and the phenomenon was studied as early as 1866 by E. Mach, and the results were published in the Proceedings of the Vienna Academy of Sciences under the title "Ueber die Physiologische Wirkung räumlich-vertheilter Lichtreize." A study of this pseudo diffraction effect showed the authors that their earlier work on the wave nature of the Röntgen rays fell to the ground, and that previous investigations in which the distance between the Crookes tube and the sensitive plate was as much as 24 meters and the time of exposure 80 hours, and in which double-flowed plates and strengthening screens were used, are worthless. The authors, moreover, are convinced that the eventual wave length of the X-rays must be of far smaller value than has been supposed. New experiments were then undertaken to test the question whether there are true refraction effects with X-rays. The authors believe that such effects will be found and that the wave length of the rays lies under a tenth of $\mu\mu$.

C. H. Wind also discusses the question whether the refraction phenomena studied by Haga and himself are due to certain vibrations of the source of light 3000 times smaller than the time of vibration of yellow light, and that the emission of the X-ray system must be ascribed to a nature of vibration entirely different from that of ordinary light. He comes after an analytical discussion of this question to the conclusion that this conclusion is not justified (Wied. Ann., No. 8, 1899, pp. 884–901).

M. Maier has also investigated the question of the refraction of the X-rays and states that he has discovered interference phenomena which indicate the wave nature of these rays. He finds wave lengths 0·000015^{mm} in length. His experiments do not decide the question of the transversality of these waves, for no polarization phenomena were in evidence.—*Wied. Ann.*, No. 8, 1899, pp. 903–916. J. T.

9. *Radio-active substances.*—E. DE HAËN has discovered two preparations of uranium earth which possess the property of exciting X-rays in a remarkable degree. Preparation A shows the phenomenon of the Becquerel rays; excites fluorescence of barium platinum-cyanide screens, even through substances opaque to light; acts upon photographic plates; makes air conducting for electricity, and has, moreover, the hitherto undiscovered property of being self-luminous. Preparation B proves to have in general the peculiarities of preparation A. The excitation of a screen is more intense, the self-lighting is much weaker.—*Wied. Ann.*, No. 8, p. 902. J. T.

10. *Physikalische Zeitschrift*, No. 1–2, pp. 1–38, Leipzig (S. Hirzel).—Physicists will be interested in the appearance of the *Physikalische Zeitschrift*, of which the first number (1 and 2) was

issued on the 1st of October. This new periodical is to be conducted by Dr. E. Riecke and Dr. H. Th. Simon of Göttingen, aided by a considerable staff of co-workers, for the preparation of abstracts. It is to be issued in weekly numbers at a cost of 5 marks for three months. As a prompt means by which physicists may present the results of their work, it will doubtless prove of great value and contribute much to the progress of science. The portion devoted to abstracts and book notices also promises to be carefully and thoroughly conducted.

II. GEOLOGY AND NATURAL HISTORY.

1. *On Geological Time.*—The address of Sir ARCHIBALD GEIKIE, before the Geological Section of the British Association at the recent Dover meeting, was an able presentation of the profound problem of geological time. He opened with a historical summary of the successive phases of the discussion, beginning with the writings of Hutton, to whom modern geology owes so much. The conclusion of Hutton's philosophy is thus stated, "that the history of the earth occupied prolonged though indeterminate ages in its accomplishment." The Uniformitarian School, following, founded on the teachings of Hutton and Playfair, came to believe that an absolutely unlimited extent of time was at the disposal of geologists. In 1862, however, the discussion of the subject was first undertaken from the physical side, when Sir William Thomson (Lord Kelvin), in his paper on the secular cooling of the earth, announced the conclusion that the age of the earth must be more than 20 millions but less than 400 millions of years. Since that time the physical arguments have been restated and reargued by Lord Kelvin and others, the latest conclusion of the same physicist (Victoria Institute address of 1897, see this Journal, vii, 160), being that the age "was more than twenty and less than forty millions of years and probably much nearer twenty than forty."

This conclusion, however, has not been universally accepted by physicists, for example, Professor Perry in 1895 closed a discussion intended to show the uncertainty of the physical data upon which the estimate was based, by the remark: "It is to be observed that if we exclude everything but the arguments from mere physics the *probable* age of the earth is much less than any of the above estimates; but if paleontologists have good reasons for demanding much greater times, I see nothing from the physicist's point of view which denies them four times the greatest of the estimates."

After this historical summary, the writer goes on to protest vigorously against the ignoring of the evidence adduced by geologist and paleontologist which has often characterized the discussions of the physicist. He writes: "It is difficult satisfactorily to carry on a discussion in which your opponent entirely ignores your arguments, while you have given the fullest attention to his.

In the present instance, geologists have most carefully listened to all that has been brought forward from the physical side. Impressed by the force of the physical reasoning, they no longer believe that they can make any demands they may please on past time. They have been willing to accept Lord Kelvin's original estimate of 100 millions of years as the period within which the history of life upon the planet must be comprised; while some of them have even sought in various ways to reduce that sum nearer to his lower limit. Yet there is undoubtedly a prevalent misgiving, whether in thus seeking to reconcile their requirements with the demands of the physicist they are not tying themselves down within limits of time which, on any theory of evolution, would have been insufficient for the development of the animal and vegetable kingdoms."

Going on to discuss the evidence as to the rate of change and intensity of action of geological changes in earlier geological times as compared with the more recent, he says: "They [geologists] have been unable to discover any indication that the rate of geological causation has ever, on the whole, greatly varied during the time which has elapsed since the deposition of the oldest stratified rocks. They do not assert that there has been no variation, that there have been no periods of greater activity, both hypogene and epigene. But they maintain that the demonstration of the existence of such periods has yet to be made. They most confidently affirm that whatever may have happened in the earliest ages, in the whole vast succession of sedimentary strata nothing has yet been detected which necessarily demands that more violent and rapid action which the physicists suppose to have been the order of nature during the past.

"So far as the potent effects of prolonged denudation permit us to judge, the latest mountain-upheavals were at least as stupendous as any of older date whereof the basal relics can yet be detected. They seem, indeed, to have been still more gigantic than those. It may be doubted, for example, whether among the vestiges that remain of Mesozoic or Palæozoic mountain-chains any instance can be found so colossal as those of Tertiary times, such as the Alps. No volcanic eruptions of the older geological periods can compare in extent or volume with those of Tertiary and recent date. The plication and dislocation of the terrestrial crust are proportionately as conspicuously displayed among the younger as among the older formations, though the latter, from their greater antiquity, have suffered during a longer time from the renewed disturbances of successive periods." And further: "It is thus abundantly manifest that even in the most ancient of the sedimentary registers of the earth's history, not only is there no evidence of colossal floods, tides and denudation, but there is incontrovertible proof of continuous orderly deposition such as may be witnessed to-day in any quarter of the globe. The same tale, with endless additional details, is told all through the stratified formations down to those which are in the course of accumulation at the present day."

A consideration of the paleontological evidence shows how strong an argument can be make on this side. He concludes: "Until, therefore, it can be shown that geologists and paleontologists have misinterpreted their records, they are surely well within their logical rights in claiming as much time for the history of this earth as the vast body of evidence accumulated by them demands. So far as I have been able to form an opinion, one hundred millions of years would suffice for that portion of the history which is registered in the stratified rocks of the crust. But if the paleontologists find such a period too narrow for their requirements, I can see no reason on the geological side why they should not be at liberty to enlarge it as far as they may find to be needful for the evolution of organized existence on the globe. As I have already remarked, it is not the length of time which interests us so much as the determination of the relative chronology of the events which were transacted within that time. As to the general succession of these events, there can be no dispute. We have traced its stages from the bottom of the oldest rocks up to the surface of the present continents and the floor of the present seas. We know that these stages have followed each other in orderly advance, and that geological time, whatever limits may be assigned to it, has sufficed for the passage of the long stately procession.

"We may, therefore, well leave the dispute about the age of the earth to the decision of the future. In so doing, however, I should be glad if we could carry away from it something of greater service to science than the consciousness of having striven our best in a barren controversy, wherein concession has all to be on one side and the selection of arguments entirely on the other. During these years of prolonged debate I have often been painfully conscious that in this subject, as in so many others throughout the geological domain, the want of accurate numerical data is a serious hindrance to the progress of our science. Heartily do I acknowledge that much has been done in the way of measurements and experiments for the purpose of providing a foundation for estimates and deductions. But infinitely more remains to be accomplished. The field of investigation is almost boundless, for there is hardly a department of geological dynamics over which it does not extend. The range of experimental geology must be widely enlarged, until every process susceptible of illustration or measurement by artificial means has been investigated. Field-observation needs to be supplemented where possible by instrumental determinations, so as to be made more precise and accurate, and more capable of furnishing reliable numerical statistics for practical as well as theoretical deductions."

The writer closes by an enumeration of some of the different lines of investigation which, if followed out, might be expected to lead to more definite knowledge in regard to this fundamental question, and suggests that the coming International Geological Congress to be held in Paris in 1900, might well organize a system of combined observations looking to this end.

2. *An Estimate of the Geological Age of the Earth;* by J. Joly, University of Dublin.—The latest contribution to the subject ably argued by Sir Archibald Geikie at the meeting of the British Association (see above), is that by Professor J. Joly in a paper published in vol. vii of the Scientific Transactions of the Royal Dublin Society, September, 1899. In this interesting memoir the author discusses the geological age of the earth since the formation of the ocean, basing his calculations upon the time required to supply to it the amount of sodium now present in the water. He starts with the assumption of the Uniformitarian, that the processes now going on may be considered to have continued essentially as at present for the whole period in the past here concerned. The basis on which his argument is placed will be understood from the following paragraphs.

"In the method of approaching the question of the Age of the Earth advanced in this paper, the foregoing tenet* requires only acceptation in part—that part of it which refers to the removal of the land surface by *solution.* It has to be accepted as a preliminary step that this, on the whole, has been constant. Herein are involved a constancy, within certain fairly wide limits, of rainfall over the land areas; a constancy within fairly wide limits (which can roughly be defined) of the exposed land area, and a constancy in the nature and rate of solvent actions going on over the land surfaces. The grounds on which this amount of uniformity is accepted are given in this paper. One other tenet must be accepted, that the primeval ocean—that formed on first condensation of the water upon the land—did not contain the amount of dissolved sodium now entering so largely into its constitution. The grounds upon which this is claimed are also dealt with further on.

"How can these data be used to determine what may be termed the Epigene Age of the Earth? In the sea or in its deposits those elements are recognizable which enter also into the constituents of the solid part of the Earth's crust. In the rivers these elements are also recognizable as being continually poured into the ocean. Very accurate estimates of the quantities of these elements in the ocean exist. The dissolved contents of many of the great rivers of the Earth and the mean composition and mean volume of the entire river discharge have been estimated.

"Now if any of the elements entering the ocean is not again withdrawn, but is, in a word, 'trapped' therein, re-appears as no extensive marine deposit, and is not laid down sensibly upon its floor; and if the amount of Uniformity already defined is accepted, evidently in the rate of annual accretion by the ocean from the rivers of this substance and the amount of it now in the ocean, the whole period since the beginning of its supply can be estimated.

*[That the rate of removal of the subærial land surface—by solution and transportation—has been on the whole uniform.]

"Such an element is sodium. We take for this calculation the element alone, thus avoiding the obscure question of its ionization, which does not concern the issue. The quantity of sodium now in the sea, and the annual rate of its supply by the rivers, lead, it will be seen, to the deduction that the age of the Earth is 99 million years. Certain deductions from this are—it will be shown—warranted, so that the final result of this paper will be to show that the probable age is about 89 million years. Also, that this is probably a major limit, and that considerable departure from uniformity of activities could hardly amend it to less than 80 million years."

The actual calculation is very simple, since in the first place the total mass of the ocean is known approximately and also its composition, hence the total amount of sodium now present in it is obtained; further, the total amount of water discharged by the rivers into the ocean is known, with their average percentage of solid matter, sodium included, and this gives the mass of sodium annually added to the ocean. The quotient obtained is 99,400,000 years.

A minute discussion is given as to the probable original condition of the ocean and the state in which the chlorine now combined as sodium chloride probably existed. It is concluded that of the total chlorine in the original ocean, probably some 14 per cent may have existed as sodium chloride derived from the rapid denudation of the original rocks. This conclusion is based on the view that the chlorine now in the ocean must have been originally free in the atmosphere and hydrosphere, probably combined with hydrogen. The first result, (1) 99·4 millions of years, obtained, as stated, on the assumption that no free acid existed in the primeval atmosphere and that the total river supply of sodium was derived at a uniform rate from the rocks, is now (2) reduced to 86·9 million, assuming that the free acid in the original atmosphere (see above), less that subsequently supplied by rivers, attacked the original rocks and became neutralized in a negligible time. This again (3) becomes 89 millions if a period of acid denudation at a rate five times the average rate of present subærial denudation is assumed. And finally (4) the result 89·3 millions of years is obtained in a fourth assumption that 10 p. c. of the sodium chloride in the river discharge was derived from the ocean.

Account is taken of the deposits of rock salt at various points, as, for instance, the salt range of the Punjab; but it is shown that the amount involved is relatively so small as not to seriously affect the problem. Other points are also considered, as to the probable uniformity of denudation by solution dependent upon land area and rainfall; also the solvent denudation of the ocean itself; but for the details of these, reference must be made to the original memoir.

One interesting relation brought out in the discussion is that existing between the soda (Na_2O) and potash (K_2O) in the average igneous and eruptive crust-rock as compared with that in sediments. The ratio, as obtained by Clarke, is 3·61 : 2·83, or $Na_2O : K_2O = 1·29 : 1$. From rock analyses quoted by Rosenbusch, the ratio 1·22 is obtained. For sedimentary rocks, however, the ratio (from Rosenbusch) 0·59 : 1 is obtained. The author discusses the bearing of these facts and finally concludes that "whereas the sodium compounds tend to accumulate in the waters of the ocean, the potassium compounds tend to be stored in the solid form or retained upon the land; and that to the causes which bring about this separation, and not to any differences in part processes of denudation, the remarkable scarcity in the ocean of potassium relatively to sodium is to be ascribed."

As connected with the same subject he notes that while roofing slates of Cambrian or Silurian age (quoting Rosenbusch and Clarke) contain 4·1 to 5·6 p. c. alkalies, and Devonian slates have 3·04 to 3·54; recent sediments contain a much smaller amount, e. g. 1·47 p. c. in the case of the Rhine, 1·96 for the Nile, etc.

3. *Recent Publications of the United States Geological Survey*, Charles D. Walcott, Director.—The following volumes have been recently issued by the U. S. Geological Survey:

NINETEENTH ANNUAL REPORT FOR 1897–98. Part I, *Director's Report*, including Triangulation and Surveying (see this Journal, vol. vii, p. 166).

Part IV, *Hydrography*, F. H. NEWELL, Chief of Division. Pp. viii, 814 with plates I to CXVIII. The results of the recent work in this highly important department of the Survey are now presented by themselves in a single volume of generous dimensions. For ten years past observations have been systematically carried on, having as their object the collection of data in regard to the fluctuation of the waters of prominent streams throughout the United States. The importance of the knowledge thus gained both from an economic and a scientific standpoint can readily be estimated. The opening chapter of the present volume by F. H. Newell, assisted by various observers (pp. 1–633), explains with numerous illustrations the methods of work, and then goes on to give the results of measurements of different rivers taken in natural geographical order. Among the special reports included may be mentioned one by Dwight Porter (pp. 34–111) on the streams of Maine and another by J. P. Lippincott (pp. 540–632) on the water supply of San Bernardino valley. The latter report is especially interesting as giving with many illustrations an account of the method of storing and distributing water, and the striking results so obtained, in a region which depends almost entirely upon artificial irrigation. Special chapters on the rock waters of Ohio, by Edward Orton (pp. 633–718, plates LXXI–LXXIII), and on the geology and water resources of Nebraska west of the 103d meridian by N. H. Darton (pp. 710–780, plates LXXIV–CXVIII) also certain much interesting matter.

Part VI. *Mineral Resources of the United States for* 1897, DAVID T. DAY, Chief of Division. This report, the fourteenth of the series, appears in two volumes, each separately paged and indexed. The first (pp. 651) contains the Metallic Products with coal and coke, the second (pp. 706) Non-metallic Products except coal and coke. The value and scope of this report, to which many specialists have contributed, are too well known to need further comment here.

MONOGRAPHS: XXXI, *Geology of the Aspen Mining District, Colorado*, by JOSIAH EDWARD SPURR, pp. xxxv, 60. With an Atlas containing folio plates. This report will be noticed later.

Also XXIX by B. K. EMERSON and XXXI by the late JOHN STRONG NEWBERRY; both of these are noticed below.

BULLETIN, No. 162. *Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy* for 1898, by FRED BOUGHTON WEEKS. The value of this series is much increased by the admirable promptness with which the successive numbers appear.

4. *Geology of Old Hampshire County, Massachusetts, comprising Franklin, Hampshire, and Hampden Counties*, by BENJAMIN KENDALL EMERSON, pp. 1–782, plates i–xxxv, 1898. U. S. Geological Survey, Charles D. Walcott, Director. Monograph XXIX.—This elaborate description of the geology of central Massachusetts was begun in 1873, and thus contains the mature opinions of the author, based on a detailed study of the region. The classification of the rocks, which (except the Triassic sandstone) are crystalline limestones, granite schists, gneisses and diabases, is constructed on a chronologic basis.

The following general section of the rocks in the Berkshire hills and Connecticut valley will indicate the author's interpretation and the names adopted in the report:

Trias.
  Black Rock diabase (intrusive).
  Chicopee shale.
  Longmeadow sandstone.
  Granby tuff.
  Mount Holyoke diabase (interbedded).
  Sugar Loaf arkose.
  Mount Toby conglomerate.
  Unconformity.

Eruptives, mostly post-Carboniferous.
  Granite.
  Granitite.
  Pegmatite.
  Albitic granite.
  Tonalite.

Carboniferous (no representative in the region).

Devonian.
  Bernardston mica-schist.
  Bernardston amphibolite.
  Bernardston quartzite.
  Bernardston limestone.
  Vernon gneiss.
  Unconformity.

Upper Silurian.
  Leyden argillite.
  Conway dark corrugated mica-schist with garnets.
  Goshen flaggy biotitic muscovite-schist with quartzite and limestone beds.
  Unconformity.
Lower Silurian.
  Hawley actinolitic chlorite-schist, amphibolite, pyrite, and hematite beds.
  Savoy chloritic sericite-schist.
  Chester amphibolite, with emery, serpentine, steatite, and saxonite.
  Rowe quartzose sericite-schist with amphibolite beds.
  Hoosac albitic sericite schist.
Cambrian.
  Cheshire white granular quartzite.
  Becket white conglomerate-gneiss.
  Unconformity.
Algonkian.
  Washington blue quartz-gneiss.
  Tyringham stretched biotite-gneiss.
  East Lee black biotite-hornblende-gneiss.
  Hinsdale coarse chondrodite-limestone.
  Hinsdale granitoid gneiss. W.

5. *The Later Extinct Floras of North America*, by JOHN STRONG NEWBERRY; A Posthumous Work, edited by ARTHUR HOLLICK, pp. i–xvii, 1–295, plates i–xlvii, 1898. U. S. Geological Survey, Charles D. Walcott, Director, Monograph XXXV. —In this volume are included illustrations of 174 species of Cretaceous and Tertiary plants, gathered from 52 localities of North America, together with such notes and descriptions as were found among his manuscript after Dr. Newberry's death.

Figures of some of the species have been previously distributed and names (MSS.) published, but in the present work all unpublished descriptions and notes found among the author's papers are edited and their reference to the figures indicated by the editor, Dr. Hollick, whenever clear, and whenever uncertain with the editor's comments. W.

6. *Geological Survey of New Jersey, Annual Report of the State Geologist for the Year* 1898, pp. 1–244 and 1–100, plates i–v and i–xxii, 1899.—Besides the customary reports on various geological problems, an appendix of more than ordinary interest is furnished by GIFFORD PINCHOT on "A study of Forest Fires and Wood Production," illustrated by numerous photographic reproductions of the effects of the fires upon the forests in general and the individual trees of various ages. W.

7. *Report on the Surface Geology and Auriferous Deposits of Southeastern Quebec*, by R. CHALMERS, pp. 5–160, plate i. Geological Survey of Canada, Annual Report, vol. X, 1898, G. M.

Dawson, Director. Part J, No. 670.—The gold-bearing region described in this report extends from Memphremagog Lake on the west, to the Etchemin River and Township of Ware on the northeast, and from the crystalline range of mountains nearest the St. Lawrence (the Sutton Mountain anticline) southeastward to the International boundary.

The author concludes from his study of the region that the "original source of this precious metal was in the oldest rocks of the 'Eastern Townships,' namely the pre-Cambrian or Huronian (?) of the three mountain ranges which traverse it. The Cambrian and Cambro-Silurian rocks are probably composed largely of materials derived from the pre-Cambrian in their disintegration and waste, and the gold they contain, as well as that met with in the alluviums derived from them, probably owes its origin likewise to the same source. Concentrating processes have been in operation ever since. During the formation of the Cambrian and Cambro-Silurian rocks there may have been some mechanical concentration of the gold in these, as the sediments which were derived from the pre-Cambrian in Cambrian and Cambro-Silurian times would naturally contain it in a fine state of division. It is difficult except on this supposition to account for its presence in some areas and its scarcity or absence in others. But the chief concentration seems to have been in some of the quartz veins at a later stage in areas of eruptive diorites and other intrusive rocks, and still later in the alluviums of the river-valleys during the wear and waste of the land surface." W.

8. *The History of the European Fauna*, by R. F. SCHARFF, pp. 1–364, 1899 (The Contemporary Science Series, Walter Scott).—This book is a study in the origin and migration of the component elements of a living fauna. The present fauna of Britain is recognized as having its origin in migration to the region of an Arctic, a Siberian, an Oriental, a Lusitanian (southwest Europe) and an Alpine fauna. Regarding the time and order of these migrations, the author says, "there is considerable difference of opinion on this subject. Some believe that the British fauna is altogether post-glacial; a few think that it is partly so and the remainder glacial; others again hold that a portion is pre-glacial and the rest glacial and post-glacial. Those who have studied the subject most closely feel convinced that the southwestern or Lusitanian fauna, and also the flora, must have arrived before the Glacial period and survived the latter in these Islands. It seems reasonable to suppose, therefore, that the climate cannot have been very severe during the so-called Ice-Age. This Lusitanian fauna must be looked upon as the oldest portion of the British fauna. The Alpine and Oriental migrations arrived next. After these came the Arctic, and finally the Eastern or Siberian. As the fossil evidence is most complete with regard to the last, we are able to determine with precision not only the direction whence this migration came, but approximately its geological age. It arrived in Germany from the east after the deposition of the

lower bowlder-clay. Since the bowlder-clay is looked upon as a glacial deposit, the Siberian migration reached Central Europe after the first portion of the Glacial period had passed. In England it makes its first appearance in the Forest-Bed, which would therefore correspond to the 'Loess' formation of Central Europe. All the other migrations are older than the Siberian. They must therefore have come to Great Britain during the earlier part of the Glacial period or before it." W.

9. *The Geology of the Coolgardie Gold field;* by TORRINGTON BLATCHFORD, Assistant Government Geologist. Bulletin No. 3, Western Australia Geological Survey, A. Gibb Maitland, Government Geologist. Perth, 1899.—The Coolgardie gold field is remarkable for its rapid development—it was discovered in 1892—and for the richness of much of the ore. The prevailing rocks are designated as diorite with adjacent hornblendic and talcose schists, both intersected by numerous acid igneous dikes; a mass of granite is central in the district. Superficial deposits, in part "ironstone gravel," cover much of the region. The gold has been largely obtained from "gold reefs" intersecting the schists chiefly and dipping eastward at an angle of 60° to 80°. In addition gold has been obtained also from lenticular ferruginous patches and altered schists adjoining the igneous dikes. The alluvial deposits have also yielded much gold. The gold exported in 1894 amounted to 105,330 oz. and 1898 to 127,227 oz. The development of the region is much retarded by the deficient water supply. The average rainfall for the five years from 1894 to 1898 was only 7·01 inches, and artesian wells, though repeatedly tried, have not proved successful.

A large colored geological map of the region, on a scale of 8 inches to the mile, has been issued, in addition to the smaller one accompanying the report.

10. *Mineral Resources of Kansas for* 1899, by ERASMUS HAWORTH. Annual Bulletin of the University Geological Survey of Kansas, pp. 127, 1899, Lawrence, Kansas.—This second annual bulletin on the mineral resources of Kansas has recently been issued and contains an account of the lead and zinc mining, coal, oil, and gas, gypsum, building stone and clays, hydraulic cement, and salt.

The *salt* industry is of especial importance in the State, and the account here given of its discovery in 1887–88 and its rapid development is very interesting. Prof. Haworth, speaking of the geology of the Kansas salts, distinguishes between (1) the salt of salt marshes and of salt plains, chiefly in the northern part of the State, where the salt has been obtained from the shales of the Dakota formation; and (2) the rock salt of Central Kansas, which has been located in "salt shales" of the Permian. The thickness of the salt deposits diminishes eastward, though the exact extent on the west side of the salt lake from which the material was precipitated is as yet unknown. In a north and south direction the known salt beds cover a wider area, reaching from Anthony to

Kanopolis, thinning out northward. Thus the salt beds at Kingman are 415 feet in thickness; at Hutchinson, 380 feet; at Lyons, 275 feet, and at Kanopolis only 250. At this rate they would disappear entirely before the north line of the State is reached. It is a remarkable fact that the usual gypsum deposits do not seem to be present at localities just named, though largely represented to the northeast in Marshall County. In regard to this, Professor Haworth writes:

"It is difficult to understand how such extensive deposits of salt could be formed without a larger amount of gypsum being formed underneath them. The records of the wells at Kanopolis, Lyons, Hutchinson, Kingman and Anthony contain no reference to gypsum immediately underlying the salt beds. The question is as to what became of the calcium sulphate held in solution by the ocean water from which the rock salt was obtained. It is barely possible that during the period of the formation of the Marshall County gypsum the inland sea did not reach southward to the salt beds area, and that after gypsum was principally precipitated out of the enclosed ocean water and before concentration was carried far enough to precipitate the salt, surface movements resulted in draining this partially purified water southward over new areas from which fresh ocean water was excluded, thus permitting the continued evaporation to deposit the salt now found in the salt beds from the same water from which the Marshall County gypsum was produced. It is known that the Permian rocks, in general, become quite thin northward, entirely excluding the upper members of the Permian. So far as this has a bearing on the subject, it would tend to favor the view just expressed."

11. *Catalogus Mammalium tam viventium quam fossilium a* Doctore E. L. TROUESSART, Parisiis. Nova Editio (Prima completa). Fasciculus VI. Appendix (Addenda et Corrigenda). Index alphabeticus. pp. 1265–1469. Berlin, 1899 (R. Friedländer & Sohn).—The sixth and concluding part of this highly important work has recently been issued. It consists of an Appendix (pp. 1265–1360) containing Addenda and Corrigenda; also an exhaustive alphabetical index (pp. 1361–1469). The thoroughness with which the whole undertaking has been carried through makes it an invaluable book of reference to all zoologists.

12. *Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen.* Herausgegeben von der Deutschen Zoologischen Gesellschaft. Generalredakteur, FRANZ EILHARD SCHULZE. 5. Lieferung. *Protozoa.* Redakteur: O. BÜTSCHLI. *Sporozoa* par ALPHONSE LABBÉ. pp. 180 with 196 figures. Berlin, 1899 (R. Friedländer & Sohn).—Another work of similar exhaustive character to the above and broader scope is "Das Tierreich," published by the German Zoological Society. Earlier numbers have been repeatedly noticed in these pages. The present part, No. 5, contains the Sporozoa by Alphonse Labbé,

conservateur of the zoological collections of the Sorbonne at Paris. The classified species are briefly characterized with numerous references to authorities. Many illustrations accompany the text.

13. *Zoological Results based on Material from New Britain, New Guinea, Loyalty Islands and elsewhere,* collected during the years 1895, 1896, and 1897; by ARTHUR WILLEY. Part III, (May, 1899), pp. 207–356. Cambridge, 1899 (University Press).—Parts I and II of this work have already been noticed; the third part, recently issued, contains the following papers: Orthogenetic variation in the shells of Chelonia, by Hans Gadow; pp. 207–222, plates xxiv–xxv. Enteropneusta from the South Pacific, with notes on the West Indian Species, by Arthur Willey; pp. 223–334, plates xxvi–xxxii. A collection of Echiurids from the Loyalty Islands, New Britain and China Straits, with an attempt to revise the group and to determine its geographical range, by Arthur E. Shipley; pp. 335–356, plate xxxii.

14. *Proceedings of the Fourth International Congress of Zoology.* Cambridge, 22nd–27th August, 1898. Edited by ADAM SEDGWICK, M.A., F.R.S; pp. xv and 432 with 15 plates. London, 1899 (C. J. Clay & Sons).—This valuable volume has recently been issued and contains, in addition to the account of the meetings of the Congress at Cambridge in 1898, a large number of papers presented at that time, with the discussions which accompanied their reading.

15. *The Birds of Eastern North America: Water Birds.* Part I. Key to the Families and Species. By CHARLES B. CORY, Curator of the Department of Ornithology in the Field Columbian Museum. Pp. ix, 142.—This excellent and liberally illustrated volume appears as a special edition printed for the Field Columbian Museum.

16. *A Hand-list of the Genera and Species of Birds;* by R. BOWDLER SHARPE, LL.D. Vol. I, pp. xxi and 303, London, 1899.—This recent addition to the Catalogues published under the auspices of the British Museum, including species both recent and fossil, has been carefully prepared by Dr. Sharpe of the Zoological Department. Many ornithologists at home and abroad have contributed to its accuracy and completeness.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Physical Society.*—A meeting of the recently organized American Physical Society was held in Fayerweather Hall, Columbia University, New York City, on October 28th. The program announces the presidential address delivered by Professor Henry A. Rowland and papers read by various of the members. Four regular meetings of the Society are proposed for each year, ordinarily to be held in New York; the annual meeting is appointed for the last week of December. The Society will issue a Bulletin containing reports of the meetings with notices of papers read or presented. The Secretary of the Society is Professor Ernest Merritt.

2. *Transactions of the American Microscopical Society*, edited by the Secretary. Twenty-first annual meeting held at Syracuse, N. Y., August 30th, 31st, and September 1st, 1899. Vol. xx, pp. 369 with 32 plates.—The latest volume of the Transactions of the American Microscopical Society, just published, contains the usual number of valuable papers. Among the more extended of these may be mentioned the following: Contributions to the histogenesis of the Caryophyllales, I, by F. E. Clements, pp. 97–164, with plates viii to xxv; the North American species of the genus Atax (Fabr.) Bruz, by R. H. Wolcott, pp. 193–260, with plates xxviii–xxxii; Fresh water investigations during the last five years, by Henry B. Ward, pp. 261–336.

A paper by A. Mansfield Holmes (pp. 177–188) gives the results of some observations as to the effect of altitude on the red blood cells. It is shown that a sudden change from a low to a high altitude produces a rapid increase in the number of red cells, and a descent to a lower altitude, a rapid decrease. The former change, however, takes place immediately, the number continuing to increase during a residence on a mountain; but the diminution on descent, though rapid, is not so pronounced as the rate of increase. The effect of altitude is thus explained: that the increasing need of oxygen at higher points calls for greater activity of the total volume of red cells and brings, therefore, into activity many which under different conditions would remain more or less quiescent in deeper portions of the body.

3. *A Primer of Forestry.* Part I: The Forest. By GIFFORD PINCHOT; pp. 88 with 47 plates. Washington, 1899. Bulletin No. 4, U. S. Department of Agriculture, Division of Forestry.—This little book, with its numerous illustrations, presents in very attractive form the subject of forestry newly developed in this country, and which, under the guidance of Mr. Pinchot and others, it is hoped will yield important fruit. The author shows how a forest is to be regarded as an organic whole, and traces its progress through the time of full maturity to the inevitable end. An interesting chapter is that devoted to the numerous enemies of the forest, as fire, the reckless use of the axe, insects, and others.

4. *Statistical Methods with special reference to Biological Variation;* by C. B. DAVENPORT, Harvard University. New York, 1899 (John Wiley & Sons).—This little volume contains in very concise and clear form a series of mathematical tables, formulas, etc., likely to prove valuable to the working biologist in his statistical work on recently developed lines. The subjects of the preliminary chapters are: The methods of measuring organisms; the seriation and plotting of data and the frequency polygons; the classes of frequency polygons; correlated variability. The mathematical tables follow, accompanied by concise explanations as to their use.

5. *Harper's Scientific Memoirs*, edited by J. S. Ames, Ph.D. Volumes v, vi, and vii of this valuable series (see vol. vi, pp. 199, 504) have been recently issued. Their subjects are as follows:

The Laws of Gases. Memoirs by Robert Boyle and E. H. Amagat. Translated and edited by Professor Carl Barus.

The Second Law of Thermodynamics. Memoirs by Carnot, Clausius, and Thomson. Translated and edited by Dr. W. F. Magie.

The Fundamental Laws of Electrolytic Conduction. Memoirs by Faraday, Hittorf, and F. Kohlrausch. Translated and edited by Dr. H. M. Goodwin.

OBITUARY.

Edward Orton, Professor of Geology in the Ohio State University, died at Columbus, Ohio, Oct. 16th, in the seventieth year of his age. Professor Orton is chiefly known among scientific men by his contributions to Geology. Since 1865, he has been a resident of Ohio, and, while his labors have extended to all branches of geological science, his close watch of the exploitation of petroleum and natural gas, in his own and the neighboring States of Pennsylvania and Indiana, has given him a place of preeminence as interpreter of these important geological products. He took part in the preparation of volumes 1, 2 and 3, of the reports of the Geological Survey of the State of Ohio, and as State Geologist, issued volumes 4, 5, 6 and 7. He was appointed State Geologist in 1882, and has held that position up to the present year. In 1897, he was elected president of the Geological Society of America, and as president of the American Association for the Advancement of Science, presided at the recent meeting of the Association, in Columbus, in August last. Professor Orton was a man of broad culture and of influence outside his chosen science. Born at Deposit, Delaware Co., N. Y., he entered Hamilton College, graduating in 1848. He spent a year in the Lane Theological Seminary, and in 1852, took a course of studies in chemistry and botany at the Lawrence Scientific School. For three years he was professor of Natural Science in the State Normal School at Albany. He was for a time president of Antioch College, Yellow Springs, Ohio, and then became president of the Ohio Agricultural and Mechanical College, which has now become the State University. He resigned the presidency and became State Geologist in 1882. He was greatly beloved and esteemed by those who knew him. A fellow-townsman writes of him as follows: "In him were combined the deep thinking of the philosopher, the research of the scholar, the impulses of an honorable man, the manners of a gentleman, combined with infinite liberality, toleration and affability. As teacher, lecturer, college president and man he distinguished himself from his fellow-men without falling victim to the pride which too often goes hand in hand with greatness." Dr. Orton received the degree of Ph.D. from Hamilton College in 1848, and LL.D. from Ohio State University in 1881.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLV.—*The Highest Aim of the Physicist*; by HENRY A. ROWLAND.

[ADDRESS DELIVERED TO THE PHYSICAL SOCIETY OF AMERICA BY THE PRESIDENT AT ITS MEETING IN NEW YORK, OCTOBER 28, 1899.]

GENTLEMEN AND FELLOW PHYSICISTS OF AMERICA—We meet to-day on an occasion which marks an epoch in the history of physics in America; may the future show that it also marks an epoch in the history of the science which this society is organized to cultivate! For we meet here in the interest of a science above all sciences which deals with the foundation of the Universe, with the constitution of matter from which everything in the Universe is made and with the ether of space by which alone the various portions of matter forming the Universe affect each other even at such distances as we may never expect to traverse whatever the progress of our science in the future.

We, who have devoted our lives to the solution of problems connected with physics, now meet together to help each other and to forward the interests of the subject which we love. A subject which appeals most strongly to the better instincts of our nature and the problems of which tax our minds to the limit of their capacity and suggest the grandest and noblest ideas of which they are capable.

In a country where the doctrine of the equal rights of man has been distorted to mean the equality of man in other respects, we form a small and unique body of men, a new variety of the human race as one of our greatest scientists calls it, whose views of what constitutes the greatest achievement in life are very different from those around us. In this respect we form an aristocracy, not of wealth, not of pedigree, but of intellect and of ideals, holding him in the highest respect who adds the most to our knowledge or who strives after it as the highest good.

Thus we meet together for mutual sympathy and the interchange of knowledge, and may we do so ever with appreciation of the benefits to ourselves and possibly to our science. Above all, let us cultivate the idea of the dignity of our pursuit so that this feeling may sustain us in the midst of a world which gives its highest praise, not to the investigation in the pure etherial physics which our society is formed to cultivate, but to the one who uses it for satisfying the physical rather than the intellectual needs of mankind. He who makes two blades of grass grow where one grew before is the benefactor of mankind; but he who obscurely worked to find the laws of such growth is the intellectual superior as well as the greater benefactor of the two.

How stands our country, then, in this respect? My answer must still be now as it was fifteen years ago, that much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs and but little thought and money is given to the grander portion of the subject which appeals to our intellect alone. But your presence here gives evidence that such a condition is not to last forever.

Even in the past we have a few names whom scientists throughout the world delight to honor. Franklin, who almost revolutionized the science of electricity by a few simple but profound experiments. Count Rumford, whose experiments almost demonstrated the nature of heat. Henry, who might have done much for the progress of physics had he published more fully the results of his investigations. Mayer, whose simple and ingenious experiments have been a source of pleasure and profit to many. This is the meager list of those whom death allows me to speak of and who have earned mention here by doing something for the progress of our science. And yet the record has been searched for more than a hundred years. How different had I started to record those who have made useful and beneficial inventions!

But I know, when I look in the faces of those before me, where the eager intellect and high purpose sit enthroned on bodies possessing the vigor and strength of youth, that the writer of a hundred years hence can no longer throw such a reproach upon our country. Nor can we blame those who have gone before us. The progress of every science shows us the condition of its growth. Very few persons, if isolated in a semi-civilized land, have either the desire or the opportunity of pursuing the higher branches of science. Even if they should be able to do so, their influence on their science depends upon what they publish and make known to the world. A hermit philosopher we can imagine might make many useful discoveries. Yet, if he keeps them to himself, he can never claim to have benefited the world in any degree. His unpublished results are his private gain, but the world is no better off until he has made them known in language strong enough to call attention to them and to convince the world of their truth. Thus, to encourage the growth of any science, the best thing we can do is to meet together in its interest, to discuss its problems, to criticise each other's work and, best of all, to provide means by which the better portion of it may be made known to the world. Furthermore, let us encourage discrimination in our thoughts and work. Let us recognize the eras when great thoughts have been introduced into our subject and let us honor the great men who introduced and proved them correct. Let us forever reject such foolish ideas as the equality of mankind and carefully give the greater credit to the greater man. So, in choosing the subjects for our investigation, let us, if possible, work upon those subjects which will finally give us an advanced knowledge of some great subject. I am aware that we cannot always do this: our ideas will often flow in side channels: but, with the great problems of the Universe before us, we may sometime be able to do our share toward the greater end.

What is matter; what is gravitation; what is ether and the radiation through it; what is electricity and magnetism; how are these connected together and what is their relation to heat? These are the greater problems of the universe. But many infinitely smaller problems we must attack and solve before we can even guess at the solution of the greater ones.

In our attitude toward these greater problems how do we stand and what is the foundation of our knowledge?

Newton and the great array of astronomers who have succeeded him have proved that, within planetary distances, matter attracts all others with a force varying inversely as the square of the distance. But what sort of proof have we of this law? It is derived from astronomical observations on the planetary orbits. It agrees very well within these immense spaces; but where is the evidence that the law holds for smaller distances? We measure the lunar distance and the size of the earth and compare the force at that distance with the force of gravitation on the earth's surface. But to do this we must compare the matter in the earth with that in the sun. This we can only do by *assuming* the law to be proved. Again, in descending from the earth's gravitation to that of two small bodies, as in the Cavendish experiment, we *assume* the law to hold and deduce the mass of the earth in terms of our unit of mass. Hence, when we say that the mass of the earth is 5½ times that of an equal volume of water we *assume* the law of gravitation to be that of Newton. Thus a proof of the law from planetary down to terrestrial distances is physically impossible.

Again, that portion of the law which says that gravitational attraction is proportional to the quantity of matter, which is the same as saying that the attraction of one body by another is not affected by the presence of a third, the feeble proof that we give by weighing bodies in a balance in different positions with respect to each other cannot be accepted on a larger scale. When we can tear the sun into two portions and prove that either of the two halves attracts half as much as the whole, then we shall have a proof worth mentioning.

Then as to the relation of gravitation and time what can we say? Can we for a moment suppose that two bodies moving through space with great velocities have their gravitation unaltered? I think not. Neither can we accept Laplace's proof that the force of gravitation acts instantaneously through space, for we can readily imagine some compensating features unthought of by Laplace.

How little we know then of this law which has been under observation for two hundred years!

Then as to matter itself how have our views changed and how are they constantly changing. The round hard atom of Newton which God alone could break into pieces has become a molecule composed of many atoms, and each of these smaller atoms has become so elastic that after vibrating 100,000 times its amplitude of vibration is scarcely diminished. It has become so complicated that it can vibrate with as many thousand notes. We cover the atom with patches of electricity here and there and make of it a system compared with which the planetary system, nay the universe itself, is simplicity. Nay more: some of us even claim the power, which Newton attributed to God alone, of breaking the atom into smaller pieces whose size is left to the imagination. Where, then, is that person who ignorantly sneers at the study of matter as a material and gross study? Where, again, is that man with gifts so God-like and mind so elevated that he can attack and solve its problem?

To all matter we attribute two properties, gravitation and inertia. Without these two matter cannot exist. The greatest of the natural laws states that the power of gravitational attraction is proportional to the mass of the body. This law of Newton, almost neglected in the thoughts of physicists, undoubtedly has vast import of the very deepest meaning. Shall it mean that all matter is finally constructed of uniform and similar primordial atoms or can we find some other explanation?

That the molecules of matter are not round, we know from the facts of crystallography and the action of matter in rotating the plane of polarization of light.

That portions of the molecules and even of the atoms are electrically charged, we know from electrolysis, the action of gases in a vacuum tube and from the Zeeman effect.

That some of them act like little magnets, we know from the magnetic action of iron, nickel and cobalt.

That they are elastic, the spectrum shows, and that the vibrating portion carries the electrified charge with it is shown by the Zeeman effect.

Here, then, we have made quite a start in our problem: but how far are we from the complete solution? How can we imagine the material of which ordinary or primordial atoms are made, dealing as we do only with aggregation of atoms alone? Forever beyond our sight, vibrating an almost infinite number of times in a second, moving hither and yon with restless energy at all temperatures beyond the absolute zero of temperature, it is certainly a wonderful feat of human reason and imagination that we know as much as we do at present. Encouraged by these results, let us not linger too long in their contemplation but press forward to the new discoveries which await us in the future.

Then as to electricity, the subtile spirit of the amber, the demon who reached out his gluttonous arms to draw in the light bodies within his reach, the fluid which could run through metals with the greatest ease but could be stopped by a frail piece of glass! Where is it now? Vanished, thrown on the waste heap of our discarded theories to be replaced by a far nobler and exalted one of action in the ether of space.

And so we are brought to consider that other great entity—the ether: filling all space without limit, we imagine the ether to be the only means by which two portions of matter distant from each other can have any mutual action. By its means we imagine every atom in the universe to be bound to every other atom by the force of gravitation and often by the force of magnetic and electric action, and we conceive that it alone conveys the vibratory motion of each atom or molecule out into space to be ever lost in endless radiation, passing out into infinite space or absorbed by some other atoms which happen to be in its path. By it all electromagnetic energy is conveyed from the feeble attraction of the rubbed amber through the many thousand horse-power conveyed by the electric wires from Niagara to the mighty rush of energy always flowing from the Sun in a flood of radiation. Actions feeble and actions mighty from inter-molecular distances through interplanetary and inter-stellar distances until we reach the mighty distances which bound the Universe—all have their being in this wondrous ether.

And yet, however wonderful it may be, its laws are far more simple than those of matter. Every wave in it, whatever its length or intensity, proceeds onwards in it according to well known laws, all with the same speed, unaltered in direction from its source in electrified matter, to the confines of the Universe unimpaired in energy unless it is disturbed by the presence of matter. However the waves may cross each other, each proceeds by itself without interference with the others.

So with regard to gravitation, we have no evidence that the presence of a third body affects the mutual attraction of two other bodies or that the presence of a third quantity of electricity affects the mutual attraction of two other quantities. The same for magnetism.

For this reason the laws of gravitation and of electric and magnetic action including radiation are the simplest of all laws when we confine them to a so-called vacuum, but become more and more complicated when we treat of them in space containing matter.

Subject the ether to immense electrostatic, magnetic or gravitational forces and we find absolutely no signs of its breaking down or even change of properties. Set it into vibration by means of an intensely hot body like that of the sun and it conveys many thousand horse-power for each square foot of surface as quietly and with apparently unchanged laws as if it were conveying the energy of a tallow dip.

Again, subject a millimeter of ether to the stress of many thousand, nay even a million, volts and yet we see no signs of breaking down.

Hence the properties of the ether are of ideal simplicity and lead to the simplest of natural laws. All forces which act at a distance, always obey the law of the inverse square of the distance and we have also the attraction of any number of parts placed near each other equal to the arithmetical sum of the attractions when those parts are separated. So also the simple law of etherial waves which has been mentioned above.

At the present time, through the labors of Maxwell supplemented by those of Hertz and others, we have arrived at the great generalization that all wave disturbances in the ether are electromagnetic in their nature. We know of little or no etherial disturbance which can be set up by the motion of matter alone: the matter must be electrified in order to have sufficient hold on the ether to communicate its motion to the ether. The Zeeman effect even shows this to be the case where molecules are concerned and when the period of vibration is immensely great. Indeed the experiment on the magnetic action of electric convection shows the same thing. By electrifying a disc in motion it appears as if the disc holds fast to the ether and drags it with it, thus setting up the peculiar etherial motion known as magnetism.

Have we not another case of a similar nature when a huge gravitational mass like that of the earth revolves on its axis? Has not matter a feeble hold on the ether sufficient to produce the earth's magnetism?

But the experiment of Lodge to detect such an action apparently showed that it must be very feeble. Might not his experiment have succeeded had he used an electrified revolving disc?

To detect something dependent on the relative motion of the ether and matter has been and is the great desire of physicists. But we always find that, with one possible exception, there is always some compensating feature which renders our efforts useless. This one experiment is the aberration of light, but even here Stokes has shown that it may be explained in either of two ways: first, that the earth moves through the ether of space without disturbing it, and second, if it carries the ether with it by a kind of motion called irrotational. Even here, however, the amount of action probably depends upon *relative* motion of the luminous source to the recipient telescope.

So the principle of Döppler depends also on this relative motion and is independent of the ether.

The result of the experiments of Foucault on the passage of light through moving water can no longer be interpreted as due to the partial movement of the ether with the moving water, an inference due to imperfect theory alone. The experiment of Lodge, who attempted to set the ether in motion by a rapidly rotating disc, showed no such result.

The experiment of Michelson to detect the etherial wind, although carried to the extreme of accuracy, also failed to detect any relative motion of the matter and the ether.

But matter with an electrical charge holds fast to the ether and moves it in the manner required for magnetic action.

When electrified bodies move together through space or with reference to each other we can only follow their mutual actions through very slow and uniform velocities. When they move with velocities comparable with that of light, equal to it or even beyond it, we calculate their mutual actions or action on the ether only by the light of our imagination unguided by experiment. The conclusions of J. J. Thomson, Heaviside and Hertz are all results of the imagination and they all rest upon assumptions more or less reasonable but always assumptions. A mathematical investigation always obeys the law of the conservation of knowledge: we never get out more from it than we put in. The knowledge may be changed in form, it may be clearer and more exactly stated, but the total amount of the knowledge of nature given out by the investigation is the same as we started with. Hence we can never predict the result in the case of velocities beyond our reach, and such calculations as the velocity of the cathode rays from their electromagnetic action has a great element of uncertainty which we should do well to remember.

Indeed, when it comes to exact knowledge, the limits are far more circumscribed.

How is it, then, that we hear physicists and others constantly stating what will happen beyond these limits? Take velocities, for instance, such as that of a material body moving with the velocity of light. There is no known process by which such a velocity can be obtained even though the body fell from an infinite distance upon the largest aggregation of matter in the Universe. If we electrify it, as in the cathode rays, its properties are so changed that the matter properties are completely masked by the electromagnetic.

It is a common error which young physicists are apt to fall into to obtain a law, a curve or a mathematical expression for given experimental limits and then to apply it to points outside those limits. This is sometimes called extrapolation. Such a process, unless carefully guarded, ceases to be a reasoning process and becomes one of pure imagination specially liable to error when the distance is too great.

But it is not my purpose to enter into detail. What I have given suffices to show how little we know of the profounder questions involved in our subject.

It is a curious fact that, having minds tending to the infinite, with imaginations unlimited by time and space, the limits of our exact knowledge are very small indeed. In time we are limited by a few hundred or possibly thousand years: indeed the limit in our science is far less than the smaller of these periods. In space we have exact knowledge limited to portions of our earth's surface and a mile or so below the surface, together with what little we can learn from looking through powerful telescopes into the space beyond. In temperature our knowledge extends from near the absolute zero to that of the sun but exact knowledge is far more limited. In pressures we go from the Crookes vacuum still containing myriads of flying atoms to pressures limited by the strength of steel but still very minute compared with the pressures at the center of the earth and sun, where the hardest steel would flow like the most limpid water. In velocities we are limited to a few miles per second. In forces to possibly 100 tons to the square inch. In mechanical rotations to a few hundred times per second.

All the facts which we have considered, the liability to error in whatever direction we go, the infirmity of our minds in their reasoning power, the fallibility of witnesses and experimenters, lead the scientist to be specially sceptical with reference to any statement made to him or any so-called knowledge which may be brought to his attention. The facts and theories of our science are so much more certain than those of history, of the testimony of ordinary people on which the facts of ordinary history or of legal evidence rest, or of the value of medicines to which we trust when we are ill, indeed to the whole fabric of supposed truth by which an ordinary person guides his belief and the actions of his life, that it may seem ominous and strange if what I have said of the imperfections of the knowledge of physics is correct. How shall we regulate our minds with respect to it: there is only one way that I know of and that is to avoid the discontinuity of the ordinary, indeed the so-called cultivated legal mind. There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.

The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases: the ideal scientific mind, however, has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as, if possible, to always keep it in its proper relation to truth and error. Thus the fluid nature of electricity was once in a compartment near the truth. Faraday's and Maxwell's researches have now caused us to move it to a compartment nearly up to that of absolute error.

So the law of gravitation within planetary distances is far toward absolute truth, but may still need amending before it is advanced farther in that direction.

The ideal scientific mind, therefore, must always be held in a state of balance which the slightest new evidence may change in one direction or another. It is in a constant state of skepticism, knowing full well that nothing is certain. It is above all an agnostic with respect to all facts and theories of science as well as to all other so-called beliefs and theories.

Yet it would be folly to reason from this that we need not guide our life according to the approach to knowledge that we possess. Nature is inexorable; it punishes the child who unknowingly steps off a precipice quite as severely as the grown scientist who steps over, with full knowledge of all the laws of falling bodies and the chances of their being correct. Both fall to the bottom and in their fall obey the gravitational laws of inorganic matter, slightly modified by the muscular contortions of the falling object but not in any degree changed by the previous belief of the person. Natural laws there probably are, rigid and unchanging ones at that. Understand them and they are beneficent: we can use them for our purposes and make them the slaves of our desires. Misunderstand them and they are monsters who may grind us to powder or crush us in the dust. Nothing is asked of us as to our belief: they act unswervingly and we must understand them or suffer the consequences. Our only course, then, is to act according to the chances of our knowing the right laws. If we act correctly, right; if we act incorrectly, we suffer. If we are ignorant we die. What greater fool, then, than he who states that belief is of no consequence provided it is sincere.

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison? Why, then, has he not used it? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance.* The remedy is yet unknown. The physician is waiting for others to discover it or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth. Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of boors and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease.

But the true lover of physics needs no such spur to his actions. The cure of disease is a very important object and nothing can be nobler than a life devoted to its cure.

The aims of the physicist, however, are in part purely intellectual: he strives to understand the Universe on account of the intellectual pleasure derived from the pursuit, but he is upheld in it by the knowledge that the study of nature's secrets is the ordained method by which the greatest good and happiness shall finally come to the human race.

Where, then, are the great laboratories of research in this city, in this country, nay, in the world? We see a few miserable structures here and there occupied by a few starving professors who are nobly striving to do the best with the feeble means at their disposal. But where in the world is the institute of pure research in any department of science with an income of $100,000,000 per year. Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But $100,000,000 per year is but the price of an army or of a navy designed to kill other people. Just think of it, that one per cent of this sum seems to most people too great to save our children and descendants from misery and even death!

But the twentieth century is near—may we not hope for better things before its end? May we not hope to influence the public in this direction?

Let us go forward, then, with confidence in the dignity of our pursuit. Let us hold our heads high with a pure conscience while we seek the truth, and may the American Physical Society do its share now and in generations yet to come in trying to unravel the great problem of the constitution and laws of the Universe.

ART. XLVI.—*Notice of an Aerolite that recently fell at Allegan, Michigan;* by HENRY L. WARD.

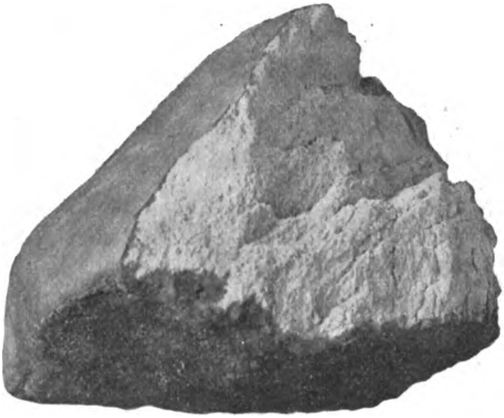
[Announced before the Rochester Academy of Sciences, Oct. 10th.]

AT eight A. M. on Monday, July 10th, of the present year there fell at Allegan, Michigan (about 32 miles S.S.W. of Grand Rapids), the aerolite herein noticed. An account of the fall was published by the Allegan Gazette in its issue of July 15th; but as I have a report of this phenomenon directly from an eye-witness, who was very near where the stone struck, who assisted in its excavation, and who was a part owner of it, the information furnished by him has been used rather than that of the newspaper. Both agree, however, in their essential features.

The newspaper account states that a piece of the meteorite was reported to have fallen at Dunningville [about eight miles N.W. of Allegan] and another on the lake shore [the nearest point of which lies about 20 miles west of Allegan]. A resident of Dunningville informs me that this report is erroneous as far as that village is concerned; as no one in the village knew anything about it except from the published report. To the best of my knowledge nothing further has been heard of the piece reported to have fallen on the lake shore; so it is presumable that this assertion also is erroneous.

Mr. Walter Price, of Allegan, writes in answer to my inquiries: "I was working on the road when the meteorite struck; it fell inside the village limits in nearly the center of the street." The exact locality is the Thomas hill on the Saugatuck road. Mr. Price continues: "It came from the northwest, and passed within about forty feet from where we were working and struck about ten rods beyond in the sand (the road was a little sandy). The first we noticed we heard a report in the sky as if a large cannon had been fired, and after that there was a rumbling noise which lasted about five minutes (this is as near as I could guess). When we heard this rumbling sound we began to look up, and saw a black ball, about the size of a man's fist, coming our way. By this time the sound had changed to a noise very much like one caused by throwing a red-hot iron into a tub of water, and when it passed by it sounded like an engine blowing off steam. There seemed to be, also, a blue streak behind it about six feet long which tapered back to a sharp point. When the meteorite struck we saw the sand fly, and it was probably five minutes before we went to dig it up. The soil was sandy and it buried itself a foot and a half. When we had thrown the loose sand from over it, it was too hot for us to handle with our hands, and we had to take a shovel to get it out of the hole. The sand was hot for about two feet around where it struck. I should think about one third of it broke into small pieces when it struck the ground. All the outside pieces had the black crust on them."

The temperature of this aerolite on reaching the earth was a matter of much interest to me. It seemed not improbable that such a large mass, said to have been about 20 inches long and 10 or 12 inches through in the thickest part, passing, for no one knows how long, through the intense cold of interstellar space should, as a mass, be cold upon reaching the earth; and that only the surface for a slight depth should become heated. Such, however, appears not to have been the case with this meteorite; which agreed with popular accounts that frequently ascribe great heat to them.



In a later communication Mr. Price writes: "In regard to the heat of the meteorite, as I understand your question, you would like to know whether it was hot all through or not. I am certain that it was hot clear through, for the pieces were all hot; and the four-pound piece I sent you was so hot that I had to keep changing it from one hand to the other in carrying it from where it fell to the wagon. As to the speed that it was traveling I cannot just express, but will say that while it was plainly visible it seemed to me that it was going at a swift speed."

The accompanying illustration is from a photograph made by a local photographer from the largest piece, said to have weighed 62½ lbs. This has not come into our hands.* We have, however, obtained for Ward's Natural Science Establishment various fragments through the agency of Mr. Price and consequently are able to describe the stone.

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* We, indeed, confidently expected to obtain it but the local merchant whose offer to act as our agent in its purchase we had accepted, on obtaining a clear title, proceeded to sell it to other parties who were, however, doubtless ignorant of our moral claim. Its whereabouts were unknown to us, when this article was written, but see the note beyond.

It is of a light ash-gray color, exceedingly friable; and covered with a black crust averaging about 1^{mm} in thickness, though in some parts reaching fully 2^{mm}, which varies from comparatively smooth in parts to wave-like crests on others.

The stone is very chondritic in structure; with the largest chondrules, composed of acicular crystals of enstatite, 3^{mm} in diameter, sparingly distributed through it. The greater number of the chondrules are much smaller; and many are very minute. An optical examination, without the use of polarized light, shows the presence of enstatite, chrysolite, some feldspar, troilite and iron. The troilite and iron are dispersed quite evenly and thickly as small irregularly-shaped grains. The specific gravity, taken from a large fragment of the stone without crust, is 3·558. No veins appear in the portions examined. Apparently this stone belongs to Meunier's group (33) called Montréjite.

The name proposed for this aerolite, *Allegan*, is fortunate in that it is at once the name of the town and of the county in which it fell.

Note.—Since the above was written I have learned that the larger mass of this aerolite is now in the U. S. National Museum at Washington.

ART. XLVII.—*Note on a New Meteoric Iron found near Iredell, Bosque County, Texas, U. S. A.;* by WARREN M. FOOTE.

IN July, 1899, the firm of Dr. A. E. Foote of Philadelphia, Pa., received from Mr. J. W. Jones of Rowlett, Texas, several ore samples for examination. Among them was a fragment of metallic iron bearing characteristic signs of meteoric origin. Later, all of the fragments of the original mass which could be traced, were purchased by the same firm. The finder supplied the following data in a certified statement: The original mass, roughly estimated at about three pounds weight and shaped like a large mussel-shell, was found by J. W. Jones while prospecting in June, 1898, on the eastern end of the Dudley sheep ranch, situated in the western corner of Bosque Co., Texas, about five or six miles southwest of the village of Iredell and one-half mile from the county line. It lay exposed in a rut seven inches deep, worn in an old road, on the west side of a small hill. The finder broke the mass, distributing pieces among strangers and passing acquaintances, who employed the metal in various ways, such as the making of knife-blades, etc. Over a year later some of these fragments were recovered, although it was impossible to get the slightest trace of a majority of them, constituting over half of the original specimen. A thorough search was made for other masses which might have fallen in the vicinity of the find, but without success.

The total weight of the known fragments is 500 grams. In exterior appearance this fall resembles most siderites, presenting an uneven, somewhat rusty surface with slight exudation of lawrencite; also streaks of schreibersite. The fragments are quite rough and angular, where broken. The three best instances of cleavage are exhibited in one specimen. These are three pairs of perfect, adjacent planes forming angles of 120°. Other less definite cleavages also indicate the crystallization to be dodecahedral. However these angles, although near one another, form no apparent relationship, which can be explained by the changes to which the mass has been subjected. It parts easily along the cleavage planes and following irregular fissures where the disintegration is most advanced. Fractured across these natural lines, it presents a glistening tin-white finely crystalline surface. Grains and plates, as much as 2^{mm} thick, of a brittle magnetic mineral, of pyritiferous aspect, are common. The smaller particles of this were so intimately mixed with the iron as to defy mechanical separation. A qualitative examination showed the presence of iron, phosphorus and nickel, indicating it to be schreibersite. The iron is soft and takes a high polish. Treating polished surfaces with dilute nitric acid develops an etching barely visible to the unaided eye. This consists of innumerable and very minute pits in the plessite, with long very fine bright lines crossing at right angles and occasionally short diagonal lines.

The composition, determined by Mr. J. Edward Whitfield from a sample of the iron, only partially freed from schreibersite, is as follows:

Iron	93·75	per cent
Nickel	5·51	
Cobalt	·52	
Phosphorus	·20	
Sulphur	·06	
	100·04	

Several siderites found in Texas bear such a close geographical relationship to this one, as to demand comparison. These are: Carlton, found in 1888 about 12 miles to the southwest in Hamilton Co., with 12·77 per cent nickel; the Red River, found in 1836 in the adjacent county (Johnson), with 8·46 per cent nickel; and Denton Co., found in 1859 about 100 miles north, with 7·53 per cent nickel. However the most marked variations from the present find are the large and distinct Widmannstätten figures which appear on etching the neighboring irons. *Iredell* may, therefore, be safely accepted as a distinct fall.

Nov. 7th, 1899.

ART. XLVIII.—*On a New Occurrence of Nepheline Syenite in New Jersey;*[*] by F. LESLIE RANSOME.

Introduction.

THROUGH the kindness of Mr. N. H. Darton, there recently came into my hands a few rock-specimens which he had collected near Brookville, N. J., in the course of general areal work on the Trenton folio of the Geological Atlas of the U. S. The specimens were stated by him to have come from a mass of trap intrusive into the Newark formation, and were supposed, when collected, to be variations from the usual and normal facies of the common trap-rock of the region. Upon examination, one of the specimens proved to be a nepheline syenite, and two of the others hornblende and biotite syenites respectively. The original specimens furnished by Mr. Darton were studied petrographically, and a chemical analysis of the nepheline syenite was made by Mr. George Steiger of the Geological Survey. Subsequently a brief visit was paid to the locality, additional material secured, and some attempt made to ascertain the relation of the syenitic rocks to the ordinary trap with which they are closely associated. This last was but partly successful, as will appear from the following preliminary notes.

Occurrence of the Nepheline Syenite and Associated Rocks.

Brookville is a small village on the Delaware, in the southwestern part of Hunterdon County, and is readily reached from Trenton by the Belvidere Division of the Pennsylvania Railroad. The nearest towns of importance are Lambertville, about 2½ miles down the river, and Stockton, about a mile upstream. As shown by the State geological map of New Jersey, the village lies almost in the middle of the broad belt of the so-called Triassic, or Newark formation, which occupies so prominent a place in the geology of the State. On the same map there is indicated the relatively small trap-mass of Mt. Gilboa, just east of Brookville, in connection with which occur the rocks which are presently to be described. It is thus seen that the nepheline syenite of Brookville occurs nearly 60 miles a little west of south from the well-known Beemerville locality, and in rocks of entirely different age and character. The Beemerville intrusions are in the Palæozoic rocks of what Salisbury[†] has called the Appalachian Zone, while the Brookville masses are in the Mesozoic rocks of the Piedmont Zone. Between these two physiographical and geological provinces lies the ancient crystalline zone of the Highlands.

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[*] Published with the permission of the Director of the U. S. Geological Survey.

[†] Physical Geography of New Jersey, Geol. Surv. of N. J., vol. v, 1895, pp. 5–6.

For a general account of the geological relations of the Mt. Gilboa trap and the surrounding sediments, the reader is re-

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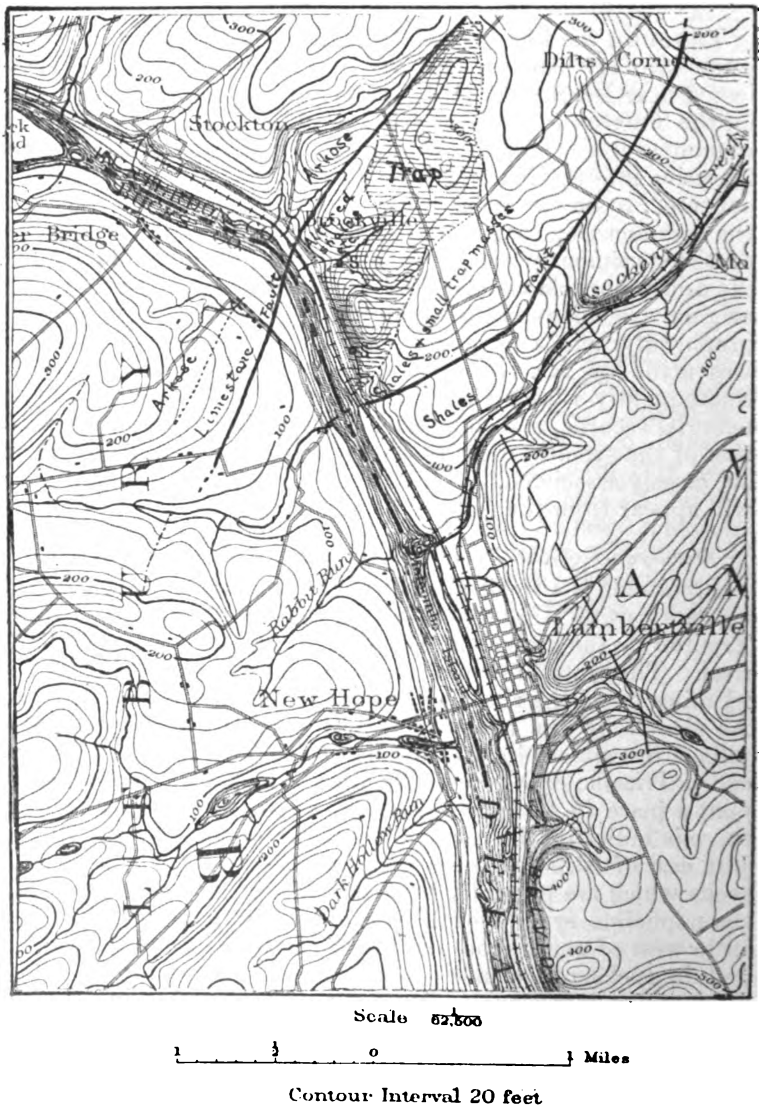

FIG. 1. Sketch Map of the Vicinity of Brookville, N. J., showing the occurrence of the nepheline syenite and other rocks rich in alkali (•S), and the relation of the outcrops to the larger geological features of the region.

ferred to a recent paper by Kümmel.* A word or two, however, may not be out of place in explanation of the accompanying sketch-map (fig. 1.), which is taken from the Lambertville topographic sheet of the U. S. Geological Survey. For the general geological data I am indebted to Mr. Darton, and to the paper by Kümmel already mentioned.

The Mt. Gilboa trap-mass lies between two faults—the Flemington fault on the northwest, and the Dilts Corner fault on the southeast, both of which are only partly shown on the sketch-map. In each case the rocks lying southeast of the line of dislocation are on the downthrow side of the fracture. Northwest of the Flemington fault, in New Jersey, lie the arkose sandstones and conglomerates of the Stockton series of the Newark, the beds dipping westerly. On the Pennsylvania side of the river however, Palæozoic limestone is exposed between the base of the Stockton beds and the fault-line. Southeast of the Dilts Corner fault, the soft red shales of the Brunswick series extend down the river to the trap masses below Lambertville. Between the two fault-lines the rocks consist of the dark shales of the Lockatong series, the Mt. Gilboa trap-mass, and several smaller bodies of trap, not shown on the sketch-map. The trap is regarded by Kümmel as intrusive, and his view is undoubtedly correct, for the shales just west of the main trap-mass are metamorphosed near the contact into quartz-biotite hornfels—a fine-grained crystalline aggregate of quartz, biotite and probably feldspar.

The nepheline syenite was found on the northwest edge of the main body of trap, just below the forks of a little brook which flows into the Delaware about a quarter of a mile south of Brookville. The exposure is not more than a few square yards in extent, and the contact with the ordinary fine-grained trap, which surrounds the nepheline syenite on at least three sides, was nowhere seen. Closely associated with the nepheline syenite and with the trap is a micaceous syenite, exposed in the bed of the brook just at the forks. Like the nepheline syenite, this rock is apparently limited in its occurrence to a small mass, the exact relations of which to the adjacent rocks were not discoverable in the field.

Near the southern end of the Mt. Gilboa trap-mass, just north of Barbour & Ireland's quarry, a small mass of syenitic rock occurs enclosed in the trap, but here also the exposures are inadequate to determine the exact extent of the mass and the relation which it bears to the trap.

The two localities referred to in the preceding paragraphs are indicated on the accompanying sketch-map by the two black dots near the edge of the trap area.

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* The Newark System or Red Sandstone Belt of New Jersey, Annual Rept. of the State Geologist, 1897, pp. 32, 75, 109-110, etc.; also pl. II. and fig. 9.

Microscopical Petrography.

Nepheline Syenite.—Megascopically this is a light gray granular rock of medium grain, which bears a very superficial resemblance to the nepheline syenite of Moultonboro, N. H. Dark amphibole is abundant, usually in slender prisms up to a centimeter in length. Biotite, while less abundant, is a conspicuous constituent in most hand-specimens, as it forms irregular poikilitic plates, usually about 5^{mm} in diameter. The dark minerals appear to constitute between a fourth and a third of the rock, but are not always uniformly distributed. They lie in a nearly white granular ground in which the lens reveals cleavage faces of feldspars, sometimes finely striated, and light brownish grains with greasy luster which presumably are more or less altered nepheline.

The microscope shows the rock to have a hypidiomorphic-granular structure and to consist of alkali feldspar > nepheline (including its alteration products) >< amphibole > biotite > cancrinite >< soda-lime feldspar > muscovite >< ægirine-augite > apatite, titanite, and fluorite. Iron ore is almost lacking, although a few grains of magnetite occur included in, or close to, the amphibole. Analcite, usually filling triangular spaces between the feldspars, is rather abundant in some sections. It is probably wholly secondary. Sericite is present as a decomposition product of the feldspars. Calcite occurs somewhat irregularly, usually associated with the analcite. The latter is also accompanied at times by small amounts of a fibrous mineral which is probably natrolite.

All the feldspars show a gray turbidity similar to that which is so common a feature of the syenitic rocks of Norway and elsewhere. Partly on this account, but more by reason of their lack of crystal outline and their confused intercrystallization, specific determination of the feldspars by optical means is not always possible. Individual grains of orthoclase pass indistinctly and irregularly into microperthitic patches or are intricately intergrown with a feldspar showing fine albite lamellæ—probably anorthoclase. This latter is often partly automorphic with reference to the orthoclase and microperthite. One area, with fine, shadowy microperthitic structure, showed distinct cleavage traces, probably basal, and the emergence of a bisectrix. The extinction referred to this cleavage was about 12°, which would seem to indicate the presence of soda orthoclase. A small part of the twinned feldspar may be albite or acid oligoclase. In general the feldspars show the lack of optical homogeneity and the indefinite patchy intergrowths frequently observed in syenitic rocks containing considerable amounts of both potash and soda.

The nepheline originally occupied areas between the feldspars, often of triangular form, but it is almost wholly decomposed and replaced by fine aggregates of secondary products, or by transparent areas of analcite. The aggregates are usually too fine to allow of the microscopic determination of their component minerals. In many cases however they consist chiefly of a sericitic mica (possibly paragonite) and analcite, the latter forming a matrix in which the minute mica scales lie.

The amphibole, which is black in the hand-specimens, agrees in its optical character with the hornblende common in many nepheline syenites.* It occurs in prisms more or less automorphic in the prism zone. The optical orientation is the usual one $a = \mathfrak{a}$, $b = \mathfrak{b}$, and $c \wedge \mathfrak{c}$ = about 9°. The pleochroism is $\mathfrak{a}$ greenish yellow, $\mathfrak{b}$ brown or dark green, and $\mathfrak{c}$ dark brownish green. The absorption is $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$. The amphibole is not optically homogeneous, a single crystal frequently showing considerable variation in color and pleochroism. It is often intergrown with biotite, the latter commonly forming an outer fringe or border to the amphibole. More rarely it is intergrown with a pyroxene which is apparently an ægirine-augite; but the latter mineral is never abundant, and is wholly wanting in some thin sections.

The biotite possesses no features of special interest beyond a tendency toward poikilitic structure and frequent intergrowths with amphibole.

Cancrinite, with its relatively strong double refraction, is a rather conspicuous constituent in some thin-sections when viewed with crossed nicols. It is clear and colorless, and occurs in irregular areas or in forms partly idiomorphic in the prism zone. It is found sometimes in little nests associated with calcite and analcite, or completely filling interstices between the feldspars, or even embedded in the latter. The prismatic cleavage is marked by fine straight lines, and the extinction is parallel. Sections approximately normal to the prism axis give a negative uniaxial interference figure. The index of refraction is distinctly lower than the balsam. The interference colors are more brilliant than those of the other minerals in the thin sections, with the exception of the muscovite. However they rarely exceed blue of the first order, and are usually orange. Confusion with muscovite is sometimes possible in a hasty examination, but the differences in the refractive indices, in the double refraction, and in the optical orientation with reference to the cleavage, readily serve to distinguish the two minerals. The cancrinite may be in part secondary, but there is no direct evidence that it is not all primary.

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* Rosenbusch, Massige Gesteine, 1896, p. 158.

Muscovite (including sericite), on the other hand, is for the most part plainly secondary in this rock, and forms a considerable part of the fine-grained aggregates which now represent the nepheline. It occurs also as a decomposition product of the feldspars. One or two larger plates of muscovite were noted, however, which may be of primary origin. As it is not practicable to distinguish optically between muscovite and paragonite in such an occurrence, the possible presence of the soda mica should not be lost sight of.

Analcite is revealed in the thin-sections as clear colorless isotropic areas, usually occupying more or less triangular spaces between the feldspars. The index of refraction is considerably below that of the balsam. The mineral is traversed by irregular cracks but shows no cleavage. It is sometimes associated with small amounts of a colorless, radially fibrous mineral which appears to be natrolite. Both minerals gelatinize readily and completely in hydrochloric acid. The analcite, as previously noted, also occurs as fine aggregates with white mica.

Apatite is a moderately abundant accessory in slender prisms up to a millimeter in length. Titanite occurs in small crystals and grains but is not abundant. Fluorite occurs sporadically in nests with calcite and analcite and is easily recognized by its pale lilac color. It is without much doubt secondary. Iron ore is almost wanting, and is practically restricted to a few grains of magnetite near, or included in, the amphibole.

A chemical analysis of the nepheline syenite, made by Mr. George Steiger of the U. S. Geological Survey, is given below. He was unable to detect any carbonic acid, and for this reason the optical properties of the mineral determined as cancrinite are given with some detail in the preceding petrographic description. It will be seen that the analysis is otherwise perfectly normal for a nepheline syenite relatively rich in soda. For comparison there is placed under II an analysis of the Red Hill nepheline syenite, which is higher in silica and lower in alumina, but otherwise agrees fairly well with the Brookville rock. The analysis of the Beemerville nepheline syenite is given under III, not so much on account of its resemblance to the Brookville rock, as to exhibit the contrast, particularly in the alkalies, in the compositions of these two New Jersey occurrences, which might have been expected to show more agreement.

Chemical Analyses.

	I.	II.	III.
SiO_2	54·68	59·01	53·56
TiO_2	·79	·81	----
Al_2O_3	21·63	18·18	24·43
Fe_2O_3	2·22	1·63	2·19
FeO	2·00	3·65	1·22
MnO	trace	·03	·10
CaO	2·86	2·40	1·24
SrO	----	trace	----
BaO	·05	·08	----
MgO	1·25	1·05	·31
Li_2O	----	trace	----
K_2O	4·58	5·34	9·50
Na_2O	7·03	7·03	6·48
Water at 100° C.	·27	·15	·93
" above 100° C.	1·88	·50	
Cl	none	----	----
F	·22	----	----
SO_3	·07	----	----
CO_2	none	·12	----
P_2O_5	·28	trace	----
	99·81	99·98	99·96
Less O	·09		
	99·72		

I. Nepheline syenite from Brookville, N. J. Geo. Steiger, analyst.

II. Nepheline syenite from Red Hill, Moultonboro, N. H. Described by Bayley, Bull. Geol. Soc. Am., vol. iii, p. 231. W. F. Hillebrand, analyst.

III. Nepheline syenite from Beemerville, N. J., Bull. 148, U. S. Geol. Surv., p. 80. L. G. Eakins, analyst.

Mica Syenite.—This is a gray, medium granular rock which has been described as occurring at the fork of the brook, close to the nepheline syenite. The hand-specimens show abundant biotite, apparently some amphibole or pyroxene, and both white and pinkish feldspars. The pinkish feldspar is somewhat unevenly distributed and shows a tendency to gather in small, ill-defined, vein-like segregations or streaks. Under the microscope the rock shows a hypidiomorphic-granular structure and is seen to consist of alkali-feldspar>biotite>pale green diopside-like pyroxene. The accessory minerals are apatite and iron ore. There is also considerable secondary chlorite, calcite, and sericite. The feldspars are generally turbid and partly decomposed to sericitic aggregates. They show the irregular mottling and fine indefinite twinning common in the alkali feldspars containing both soda and potash molecules. There is probably a little acid oligoclase present with the other feldspars. The biotite is in the main fairly fresh, but is sometimes partly chloritized. It occurs in short stout prisms or thick scales, giving abundant oblong sections with somewhat ragged ends.

The pyroxene is largely altered to calcite and chlorite. It shows a tendency toward idiomorphic form and the larger crystals frequently have a pale pinkish interior with a greenish rim, both being optically continuous. In some specimens no pyroxene is recognizable, and in others there is present a green amphibole which may exceed the pyroxene in amount. The rock generally shows considerable alteration, which renders its petrographic study unsatisfactory.

Hornblende Syenite.—This rock, which occurs, as already described, near the southern end of the trap-mass, just north of Barbour & Ireland's quarry, is a coarse-grained and slightly microlitic aggregate of flesh-colored feldspars and rather bleached-looking fibrous green amphibole. The feldspar and amphibole both show a tendency toward prismatic development, and some cleavage faces of the former are seen under the lens to be finely striated. The microscope reveals a hypidiomorphic-granular aggregate of alkali feldspar, amphibole, and a little quartz. The alkali-feldspar is turbid with the usual brown dust-like particles, and is besides usually full of wisps of secondary sericite. Nearly all the feldspar shows fine polysynthetic twinning, corresponding to both the albite and pericline laws. But the twinning is often very irregular, occupying only a portion of an individual grain, and is sometimes associated with fine microperthitic intergrowths. Some acid soda-lime feldspar (oligoclase) may possibly be present, but the bulk of the feldspar is probably an alkali-feldspar identical with, or closely related to, anorthoclase. The index of refraction is in all cases lower than the balsam. The abundant secondary sericite, and absence of calcite, suggest that the lime molecule must occupy a very subordinate position in the composition of the feldspars.

The amphibole is pale yellowish green, and occurs in allotriomorphic areas between the feldspars. In a few instances the amphibole is compact, but it usually shows a distinct fibrous structure, each area being made up of bundles of numerous slender prisms, not all of which are in parallel orientation. The pleochroism is $\mathfrak{a}$ pale yellowish green, $\mathfrak{b}$ dark yellowish green, and $\mathfrak{c}$ pale green. The absorption is $\mathfrak{b}>\mathfrak{c}>\mathfrak{a}$. The optical scheme is the usual one $a = \mathfrak{a}$, $b = \mathfrak{b}$, and $c \wedge \mathfrak{c} =$ at least 16°. Quartz occurs in subordinate amount as irregular clear grains between the feldspars. It contains fluid cavities with an occasional movable bubble, and capillary crystals of rutile (?) Apatite in stout colorless prisms is a fairly abundant accessory constituent. Titanite occurs as idiomorphic crystals, but more commonly as rounded or irregular grains. There is a little iron ore present, usually associated with the amphibole areas.

Hornblende Granite.—The specimen described under this head was supposed, when collected, to be merely a fresher facies of the hornblende syenite, as its richness in quartz was not apparent in the hand-specimen. It appeared in the field to form a part of the same small mass in the trap which afforded the specimens of syenite just described. It is a medium granular, dark gray rock, in which the feldspars are brownish in color, and show a tendency toward prismatic development in the direction of the edge $p \wedge m$. The dark constituent, apparently dark green hornblende, is fairly abundant in rather irregular prisms. A little dark mica is also visible in the hand-specimen. Under the microscope partly idiomorphic sections of decomposed feldspar and irregular plates of amphibole lie in a sort of groundmass composed of quartz and feldspar micropegmatitically intergrown. The idiomorphic feldspars appear to be, in part at least, an acid oligoclase, but many of them are completely changed into very fine sericitic aggregates. The hornblende is the common green variety and presents no unusual features. The most striking thing about the thin-section is the beautiful manner in which the quartz and feldspar, together constituting more than half the rock, are intergrown. The feldspar of these intergrowths is rendered turbid by numerous brownish dust-like particles, and its character is not easily determined by optical means alone. It is, however, without much doubt an alkali feldspar closely related to soda orthoclase or to anorthoclase, although it may be in part ordinary orthoclase. It shows occasionally the fine irregular twinning and lack of optical homogeneity which characterize anorthoclase. The quartz is always more or less intergrown with feldspar, but sometimes shows homogeneous patches of considerable size.

The Trap-rock.—The intrusive mass forming Mt. Gilboa is fairly uniform throughout. It is commonly a dark gray rock of fine to medium grain, and the structure, as visible to the eye, is granular. A typical specimen collected by Mr. Darton from near the center of the area shows under the microscope a hypidiomorphic-granular structure, and is a fairly fresh aggregate of labradorite (ab_3an_4) $>$ augite $>$ hypersthene $>$ quartz $>$biotite$><$ iron ore. It is a fine-grained gabbro in which a brown diallagic augite is intergrown with subordinate amounts of hypersthene and biotite. The quartz was the last mineral to crystallize, and is very subordinate in amount. It is sometimes micropegmatitically intergrown with a small amount of a dusty alkali feldspar, probably orthoclase. The hypersthene is not always present, and its place is sometimes taken by hornblende, as in a specimen from Barbour & Ireland's quarry. The structure on the whole is granular rather than ophitic, and the name gabbro is an appropriate designation for the trap-rock as a whole.

The Relation of the Syenitic Rocks to the Gabbro.

No evidence was detected, either in the field or through microscopical investigation, which in any way supports the hypothesis that the alkali-rich rocks are differentiated facies of, or immediately derived from the body of magma which cooled as gabbroitic trap. The former are distinctly different from the trap which surrounds them, and transitional facies appear to be wholly lacking. The trap as a whole shows rather striking uniformity wherever studied. Specimens, wherever collected, are characteristically trap-like, and afford no suggestion of such extreme differentiation as would be necessary for the production of a nepheline syenite, a mica syenite, or a hornblende granite. The syenitic masses, therefore, are either small dike-like intrusions in the trap, or else they are inclusions in the latter, floated up from some unknown terrane below, through which the trap broke. The exposures were not sufficiently good to determine which of these hypotheses is the true one. That the masses are dikes, would seem to be most inherently probable. Yet dikes might be expected to show more linear persistency than could here be detected, although the exposures were poor and the time given to their examination somewhat brief. On the whole it seems most likely, in this case, that the masses are included fragments, caught up in the trap magma at the time of its intrusion. It must be admitted, however, that the question of their origin is still an open one, which further work, with other and better exposures, may answer.

Washington, D. C., June, 1899.

ART. XLIX.—*The Fauna of the Magellanian Beds of Punta Arenas, Chile;* by Dr. A. E. ORTMANN.

BY the term "Magellanian beds" the writer designates the new Tertiary horizons* discovered by Mr. J. B. Hatcher near Punta Arenas, and described in a previous article.† The introduction of this term seems to be the more appropriate, since the stratigraphical position of these beds, and their relation to the Patagonian beds, is known, and since they differ in their paleontological character from all other deposits found in Patagonia. For the present, the writer intends to use this term only for the *marine* beds, underlying the Punta Arenas coal, that is to say, for horizons II and III of the paper quoted.

Since these beds reveal the true geological position of the Punta Arenas coal (between the Magellanian and Patagonian beds), and since there seems to prevail, as regards the age of this coal or lignite, quite an uncertainty‡, it is well to give a more detailed report on this "Magellanian" fauna, in order that it may be recognized, if found elsewhere. Since it is, however, impossible at present, to give a complete account of this fauna, and since an elaborate description illustrated by figures of the new species is at present impossible, the writer has decided to publish as soon as possible a short preliminary report on the species of marine fossils recognized in these beds, taking pains to characterize the new forms as exactly as possible chiefly by comparing them with well known species. The final report on these and other invertebrate fossils collected by Mr. Hatcher in Patagonia will be forthcoming in due time.

Ostrea torresi Philippi (Die tertiaeren und quartaeren Versteinerungen Chiles, 1887, p. 215, pl. 48, f. 8).

Magellanian beds, upper division (horizon III). Numerous specimens (21 lower, 14 upper valves).

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* Ameghino (Sinopsis Geologico-Palæontologica, Suplemento, 1899, p 12) has tried to correlate the Punta Arenas section with the Patagonian deposits, and considers the horizons here under discussion (II and III) as belonging partly to the Upper Patagonian beds (piso leonense) and partly to the transitional beds between the Patagonian and Suprapatagonian. It is, however, impossible for me to regard a deposit as Patagonian that does not contain a single Patagonian fossil. The so-called "piso leonense" (upper part of Patagonian), with an entirely different fauna, which has not been described, is not represented in Mr. Hatcher's collections, although the latter come from all imaginable horizons within the Patagonian-Suprapatagonian series.

† This Journal, December, 1898.

‡ Compare O. Nordenskjöld, Svenska Exped. till Magellansländerna, Bd. 1, No. 2, 1898, p. 19 and 23, 24; P. Dusen, ibid., No. 4 (Ueber die tertiaere Flora der Magellanslaender, 1899, p. 4).

Agreeing well with Philippi's figure. Characterized by the radial folds, which in our specimens—although they are much water-worn—are well exhibited. In all the other Patagonian oysters these radial folds are only faintly or not at all developed.

Recorded by Philippi from the Straits of Magellan.

Cardita elegantoides spec. nov.

Magellanian beds, upper part.—3 isolated right valves, 2 valves imbedded in the matrix.

Shell somewhat rounded, slightly inclined, with 19 radial ribs, which are rounded, about as broad as the intervening furrows, and nodulose. Lunula small, oblong. L. 16^{mm}, H. 14^{mm}.

This species comes very near in outline to C. elegans Lmck. (see: Wood, Eoc. Biv. Engl. 1, 1861, p. 146, pl. 22, f. 16) from the upper Eocene of England and France. Also the number of ribs agrees closely (17–20 in elegans): but there is a broader interspace between the ribs in C. elegans, and the ribs themselves are thinner and more nodulous.—C. volckmanni Philippi (l. c., p. 173, pl. 37, f. 4) from Tubul (Navidad beds) is also closely related, but has only 15 ribs.

Venus difficilis spec. nov.

Magellanian beds, upper part.—1 left and 2 right valves.—Lower part (horizon II).—2 double valves and 2 left valves.

Shell thick, oblique, inflated, posteriorly a little narrowed, apex situated in advance of or at $\frac{1}{4}$ of the length. Area long, occupying almost the whole of the posterior dorsal margin of the shell. Lunula oval, flat, exterior surface with close and regular concentric furrows, and with some concentric lines of growth (remains of ventral margins), the latter more crowded near the lower margin, and irregular. Concentric furrows sharp, not interrupted, $\frac{1}{2}$—1^{mm} distant from each other. Length of a large valve: 75^{mm}, height 64^{mm}, transverse diameter (of half shell) 18^{mm}. Apex situated at 16^{mm} from anterior end.

Comes very near to V. subsulcata Philippi (p. 115, pl. 17, f. 7), from the Cretaceous of Algarrobo, but in the latter species the concentric furrows do not extend all over the surface, but are interrupted in the middle.

Venus arenosa spec. nov.

Magellanian beds, upper part.—3 right valves.

Shell transversely elliptical, moderately swollen. Posterior end hardly narrower than the anterior. Apex situated at ca. $\frac{1}{3}$ of the length. Area indistinct, shorter than the posterior part of the dorsal margin. Nymphae $\frac{2}{3}$–$\frac{3}{4}$ as long as the area. Lunula indistinct. Exterior surface with strong concentric lines of growth, which have between them finer concentric striae (obliterated in our specimens on account of the closely adhering matrix). L. 60^{mm}, H. 44^{mm}, D. (half shell) 15^{mm}. All three specimens show the hinge teeth of a true Venus.

Characterized by the elongate form, and allied by that character to V. landbecki Philippi (p. 116, pl. 20, f. 8), Cretaceous, Algarrobo. The present species differs from landbecki by the situation of the apex, which is in the latter at $\frac{2}{7}$; the former is less swollen, and the area is indistinct.

Cytherea (*?*) *pseudocrassa* spec. nov.

Magellanian beds, upper part.—1 right valve.

Shell very thick and very convex, outline almost circular, posterior end rounded. Apex at $\frac{2}{7}$ of the length. Exterior surface concentrically striated, but the adhering matrix obscures the sculpture. L. 62^{mm}, H. 60^{mm}, D. 25.

The generic position is doubtful. Posterior tooth of the hinge divided. Ventral margin of shell not crenulated.

Characterized by the very thick shell and the almost circular outline, V. crassa Phil. (p. 128, pl. 21, f. 1), from the Pliocene Coquimbo beds of Chile, is related, but in our species the transverse diameter is greater, the hinge is different, and the apex is situated differently. Further, V. alta Phil. (p. 116, pl. 20, f. 3), from the Cretaceous of Algarrobo is an allied form, but the present species is higher, and rounded posteriorly (not "subrostrate"): V. alta is more triangular in outline.

Dosinia complanata (Phil.) (Artemis c. Philippi, l. c., p. 114, pl. 15, f. 1).

Magellanian beds, lower part. 4 left, 3 right valves, imbedded in matrix.

I cannot distinguish our specimens from Philippi's species.

This form has been found previously in the Navidad beds near Matanzas, Chile.

Glycimeris ibari (Phil.) (Panopæa i, Philippi, l. c., p. 167, pl. 35, f. 4).

Magellanian beds, lower part. 1 double valve, 4 left and 2 right valves.

Characterized by the elongate outline, arcuate ventral margin, narrower posterior end, and situation of apex.

Recorded from Magellanes and Skyring Water.

Glycimeris subsymmetrica spec. nov.

Magellanian beds, upper part.—1 right valve.

Almost identical with G. ibari, but not so much elongated, and posterior end not narrowed. Relation of H. to L. = 1 : 1, 6 (in ibari = 1 : 1, 8 to 2, 0).

Lutraria undatoides spec. nov.

Magellanian beds, lower part.—1 double valve.

Shell almost elliptic, $1\frac{1}{2}$ as long as high. Surface with strong and somewhat irregular, undulated concentric folds. Dorsal margin almost straight, ventral margin slightly arcuate. Apex at $\frac{1}{3}$ of the length, prominent, rather sharp, incurved. Anterior and posterior ends evenly rounded off and of the same height. L. 32^{mm}, H. 21^{mm}, apex at 11^{mm} from anterior end.

A remote resemblance exists to L. undata Phil. (p. 164, pl. 33, f. 8–11), from Tubul and Lebu (Navidad beds), but our species is very much shorter.

Patella pygmaea spec. nov.

Magellanian beds, upper part.—1 specimen.

Shell subconical, low, outline regularly oval. Apex situated in the anterior half. Surface with fine, crowded, a little unequal, radial ribs, crossed by concentric lines of growth, and finely granulated. L. 7^{mm}, B. 5^{mm}, H. 4^{mm}.

The position of this species may be with the genus *Acmaea*, as the thinness of the shell and the delicateness of the ribs suggest. At any rate, it is the first Patelloid shell found in Tertiary deposits of Patagonia.

Trochus philippii spec. nov.

Magellanian beds, upper part.—2 specimens.

Shell low, conical, not umbilicated. Whorls almost flat, only very slightly convex. Last whorl on the periphery of the base sharply angular, above this angular ridge there are 4 revolving ribs. Lower surface slightly convex, with 5 strong, revolving ribs, the most exterior separated from peripheral ridge by a broad space. Ribs of the lower surface with regular, strong granules; similar granules seem to have been present on the upper part of the whorls. H. 7^{mm}, diameter at the base: 11^{mm}.

Umbilical region closely agreeing with T. monilifer Lmck. from the Eocene of England and France, also the sculpture is of the same type. But T. monilifer is much higher, and the number of the revolving ribs is different.—T. macsporrani and T. fricki of Philippi, from the Navidad beds, are related, but different.

Turritella exigua spec. nov.

Magellanian beds, lower part.—Very abundant, numerous specimens.

Shell small, with 10 whorls, ca. 4 times as high as broad at the base. Suture deep, whorls convex, with 5–7 spiral ribs, which are rather crowded and often alternately stronger and weaker. The stronger ribs sometimes appear to be slightly granulated. H. 15^{mm}, D. ca. 4^{mm}.

Characterized by the small size, and convex whorls. The two small species of Turritella described by Philippi from the Navidad beds (trilirata and parvula) are easily distinguished by the flat whorls and small number of ribs.

Trochita merriami nom. nov. (= T. costellata Philippi, l. c., p. 93, pl. 11, f. 4, 1887, and Ortmann, this Journal, December, 1898, p. 480).*

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* Non T. costellata Conrad (1855 Pacific R. R. Rep., v. 7, p. 195, pl. 7, f. 3). Mr. J. C. Merriam of Berkely, Cal. has called my attention to the fact, that the specific name costellata has been preoccupied by Conrad for a species from the Miocene of California.

Magellanian beds, upper part, 1 specimen.—Lower part, 2 specimens.

Characterized by the fine radial striae of the shell.

Recorded from Lebu, Navidad beds.

Natica chiloënsis Phil. (l. c., p. 89, pl. 10, f. 12).

Magellanian beds, upper part, 2 poor specimens.—Lower part, abundant, many specimens.

This species is to be recognized by the thick and solid shell of a more or less ovate shape, with thick callus of the inner lip, which leaves a small, narrow slit open at the umbilicus.

Recorded from the island of Chiloë, Navidad beds.

Struthiolaria hatcheri spec. nov.

Magellanian beds, lower part.—8 specimens.

Closely allied to S. ornata var. densestriata v, Ihering (Rev. Mus. Paulista, v. 2, 1897, p. 292, f. 15) from the Patagonian beds. S. densestriata and the present form possess on the lower part of the last whorl a number of revolving ribs of *equal* strength, in which character both differ from S. ornata Sow. In S. hatcheri, however, the number of the ribs of the last whorl is much higher, 20–22, than in S. densestriata (13); 14–15 of these ribs are placed below the series of nodules found in the upper part of the whorl, Further, S. hatcheri is distinguished from the other form by the suture, which is not channel-like, as in densestriata, but simply rectangular. By this character it approaches S. chilensis Phil. (= ameghinoi v. Ih.), but in the latter species the suture is still less deep. H. 22^{mm}, D. 13^{mm}.

Actaeon chilensis Phil. (l. c., p. 111, pl. 13, f. 16).

Magellanian beds, lower part.—1 specimen.

Agrees well with Philippi's species.

Recorded from Navidad and Matanzas.

Bulla remondi Phil. (l. c., p. 109, pl. 13, f. 7).

Magellanian beds, lower part.—6 specimens.

The figure of Philippi does not agree with the measurements given in the text, the latter being almost identical with those of Sowerby's B. cosmophila.

Our specimens agree with the *figure* of Philippi. The measurements are: H. 13^{mm}, D. 5^{mm}, relation, 1: 2, 6 (Philippi's figure: H. 21, D. 8, rel. 1: 2, 6; Philippi's text: H. 19, D. 9, rel. 1: 2, 1; Sowerby's cosmophila: H. 24, D. 11, rel. 1: 2, 2).

Recorded from the Navidad beds of Chile, and doubtfully (see Moericke, N. Jahrb. Min. etc., Beil. 10, 1896, p. 594), from the Cretaceous beds of Chile.

In conclusion I should like to make a few further remarks on the Punta Arenas section. This section has been mentioned previously*), and Mr. Hatcher's account agrees fairly well with it, with the only exception that the uppermost fossiliferous bed (horizon V) has not been noticed by Nordenskjöld. In my previous report I have shown that this uppermost horizon agrees palaeontologically with the Suprapatagonian beds, true Patagonian beds being wanting here. This question has been settled in the meantime by Mr. Hatcher. He informs me, that in his opinion, there is no difference at all between Patagonian and Suprapatagonian deposits, both being only different *facies* of one and the same series of deposits. The Suprapatagonian facies is brought about by a prevailing sandy nature of the deposit, while in the Patagonian there is a more or less considerable admixture of calcareous matter. It is true, the Suprapatagonian facies is chiefly (but not always) developed near the top, the Patagonian near the base of the series, but between base and top these facies frequently interlock, giving sometimes the appearance of a discontinuity, which really does not exist. According to Mr. Hatcher there is no discontinuity between Patagonian and Suprapatagonian beds, as Ameghino maintains; in fact, he found it absolutely impossible to draw a line between these two deposits. Mr. Hatcher reached this conclusion by an examination of the contact of both deposits near Mt. Observation, and at numerous other places.

This fact confirms the opinion of the writer of the identity of both deposits formed some time ago, after the examination of the palaeontological material at hand, and the comparison of it with v. Ihering's records (after Ameghino) of the stratigraphical position of the respective fossils.

Further, this fact explains the lack of Patagonian beds in the Punta Arenas section: if Suprapatagonian and Patagonian beds are only different facies of one and the same series of deposits, they are practically identical; and it is quite clear that one may replace the other completely in certain localities; and this is exactly what we observe in the Punta Arenas section: the Patagonian beds are represented there not by the Patagonian, but by the Suprapatagonian "facies."

Princeton University, October 11.

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* See Nordenskjöld, l. c., 1898, p. 24, footnote. A section of this locality has been described as early as in 1873 by Mallard & Fuchs (Ann. des Mines, ser. 7, v. 3, p. 97), but this represents only deposits *above* the coal. Mallard & Fuchs mention the occurrence of a large oyster and a Pectunculus in the *lower* part of their section, while two such fossils in association are found only in the uppermost horizon (V) of Mr. Hatcher's profile. Thus this section seems to begin where Mr. Hatcher's ends.

ART. L.—*Some of the results of the International Cloud Work for the United States;*[*] by Professor FRANK H. BIGELOW.

THE general scheme of the survey of the clouds proposed by the International Cloud Commission is so widely understood, that it will not be necessary to describe it again, beyond saying that the observations undertaken by the U. S. Weather Bureau began on May 1, 1896, and ended on June 30, 1897, employing one primary base station at Washington, D. C., and 14 nephoscope stations distributed quite uniformly throughout the territory east of the Rocky Mountains. The computation of the resulting data and the arrangement for the publication follow closely the prescribed forms submitted in the circulars of the commission, and while the labor of preparation up to this point was considerable, there would be nothing of special interest to say regarding that portion of the report, the whole of which will form Part VI of the Report of the Chief of Weather Bureau for 1898.

The possession of much new data, contained in the 6,600 single theodolite observations and in the 25,000 nephoscope observations, afforded, however, a favorable opportunity for considering several of the fundamental problems of Meteorology, especially in view of the fact that they develop in the most perfect manner on the North American continent, and therefore, the discussion of the observations has been pushed far beyond the limits implied in the scheme of the commission. It will be admitted, no doubt, by all those who are conversant with the true state of meteorology, that in spite of much good work on the part of able investigators, there are still serious gaps in the series of facts needed to construct a sound theory of the history of cyclones and anti-cyclones; and, furthermore, that the existing theories are neither in agreement among themselves nor with all the known facts. It was important, therefore, to develop the facts regarding the circulation of the atmosphere without bias *ab initio;* and it was essential to so far correlate the existing mathematical analyses that their true meaning as to one another and as to the results of the observations should appear. Meteorology must always remain, not a crude branch of science as some writers erroneously maintain, but a difficult one, on account of the complications attending the physical processes and the fluid motions in the complex form presented by the atmosphere. We have attempted to show how some of the apparent obstacles can be overcome by employing the methods used in these observations and reductions, and the results are such as to stimulate students to continued efforts to finally resolve these interesting problems.

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[*] Published by permission of the Chief of the United States Weather Bureau.

A Standard System of Constants and Formulæ.

Part of the difficulty in making students generally realize that meteorological mathematics already stands upon a definite fundamental basis is due to the fact that while many papers of great merit exist, they are detached from one another, and there is no well defined system of formulæ which is common to all such related investigations. Professor Ferrel's treatises, it is true, in spite of his inattention to a consistent and clear notation, cover the ground, as he conceived the solution of the problem in a consecutive order from beginning to end. Yet many of his primary developments are exceedingly complicated; other valuable mathematical analyses have been discovered since his day; his main theory of the local cyclone has been found to be loaded with objections, so that students have expected that before long improvements would be introduced. The German school of authors, including Guldberg and Mohn, Oberbeck, Sprung, Hann and others, have followed substantially one line of thought which is characteristic of them, and though they reach many results in agreement with Ferrel's, especially in regard to the general cyclone covering a hemisphere of the earth, they have in reality radically different conceptions regarding the structure of the local cyclone. Thus, in Ferrel's case, it was assumed that the general and the local cyclone are examples of the same type of circulation, wherein the inner and the outer region of the cyclone are separated by a region where the gyratory velocity about the central axis is reduced to zero, having a positive direction inside and a negative direction outside in the lower strata, with a complete reversal as to gradient and direction in the upper strata, the entire system embracing the same fluid material in a continuous motion. The German school, on the other hand, began with the principle of the logarithmic potential, of which a common example is found in the motion of the ether as an electric current through a wire which is surrounded by a magnetic whirl. In this case there is no reversal of the direction of the gyratory motion, but instead of being a minimum at the boundary of the inner and the outer regions, it is there a maximum. The inner region is distinguished from the outer, however, by the fact that it alone has a vertical motion. This is evidently an entirely different type of local cyclone from Ferrel's. In the case of the general cyclone the American and the German schools are in much closer accord. Furthermore, some important difficulties arose from the attempt to account for the energy expended in the local cyclone, on the theory of a vertical convection due to the buoyancy of air expanded by the liberation of latent heat in large quantities upon the condensation of aqueous vapor into water. Also, some observations discussed by Dr. Hann seemed to show that the distribution of the temperature in the upper strata of cyclones and anticyclones is not consistent with the principles of the vertical convectional theory. Since there exists this lack of harmony as to the main theory of the motions of the atmosphere, it is no wonder that progress has been very slow in reducing meteorology to a strictly scientific basis on its theoretical side. Accompanying this confusion in the theory, the authors have seldom been fortunate enough to adopt the same notation for their mathematical discussions, so that the study of this subject has been unusually wearisome to all those who have had no strong motive for undertaking such work.

It seemed to me, therefore, desirable to construct a standard system of equations covering the entire subject, and to transpose the most important papers into that system, at least to such an extent that a student would have but little trouble in following the writings of one author and comparing the others, by means of this exposition. Several original solutions covering important ground have been introduced, with the object of bringing the formulæ into practical working forms. These include the development of the equations of motion in rectangular, cylindrical, and polar coördinates, the treatment of the humidity term in the barometric formulæ, the transformation of the thermodynamic equations in the stages represented by the α, β, γ, δ, processes in the formation of clouds, and in the treatment of the equation of continuity by which the vertical component of motion is connected with the horizontal in the case of the local cyclone. A complete new series of tables, adapted to practical work, was computed from these sets of formulæ, and applied throughout the discussion of the cloud observations.

The Weather Bureau Tables.

As a basis for the construction of the new tables, a system of the constants employed in meteorology was selected, and many of the immediate minor relations defined by suitable brief formulæ, the entire set showing numerous useful cross connections between the several parts. The primary constants are substantially those adopted by the International Committee, and they are so arranged in parallel columns for the Metric and the English systems as to be convenient for reference; the logarithms of the numbers are also given. Many minor problems in meteorology, which are often obscure in a wordy exposition, are readily explained by means of these defining formulæ, since these are more definite than any general explanation.

In preparing to discuss the physical processes which occur in the several cloud strata at heights ranging from the surface to an elevation of at least 15,000 meters, wherein the pressure B, the temperature t, and the vapor pressure e, pass through great changes, it was found that the existing tables were wholly inadequate for the purpose. The International and the Smithsonian Barometric Tables extend only to 2,000 meters, but the new tables are computed in metric measures from 0 to 15,000 meters, and for temperatures ranging from $-40°$ C. to $+40°$ C. for $h = 0$ to 5,000 meters, from $-50°$ to $+30°$ for $h = 5,000$ to 10,000 meters, and from $-60°$ to $+20°$ for $h = 10,000$ to 15,000 meters; similar tables have been made in English measures up to 10,000 feet, which is sufficient for our weather map reductions. There are certain practical difficulties with the existing tables in other particulars. The formula employed by them is of the form, $B_0 - B = B(10^m - 1)$, where $B_0 > B$, and m is a function of the temperature, humidity, gravity, altitude, and surface topography. It gives the correction which, added to the pressure B at a given altitude, will reduce it to B_0, the pressure at sea level. It is perceived that this is a very special case of reduction, namely, downward to sea level, whereas in cloud work we must be prepared to reduce upward as well as downward, and also where neither pressure is that at sea level. If by the above formulæ we wish to reduce upward, it must be done through approximations, because the value of B at the upper station is involved in the formula, and not the value of B_0 with which we begin. There is trouble with the humidity term, especially in the Smithsonian tables, where a certain average value of the vapor pressure is included permanently within the m, so that the humidity does not stand out by itself, and is, therefore, not available for an independent discussion. But in cloud work this is the very element most required, and it is not proper to assume either an invariable law of variation of the vapor contents, nor, as in the International tables, is it possible to measure the humidity term at the top and bottom of a column which is not in contact with the ground. For example, in reducing from the bottom to the top of a cumulus cloud, I have taken the following form of equation,

$$\log. B_0 = \log. B + m - \beta m - \gamma m,$$

where m includes the temperature, the altitude, and the topographic terms, β the humidity and γ the gravity. What is wanted is the value of B_0, and not the correction $B_0 - B$, which involves one superfluous operation in computing. The humidity term with its assumed law of vertical variation, and the gravity term here stand out distinctly by themselves, and the whole subject of humidity is easily open to treatment, and even to employing a different law without disturbing the main term, which is limited to the dry air pressures. By simple transformation the formula is available for reduction upwards; this may take place between any two fixed points whatsoever; the set of special tables to determine the heights by the barometric pressure is dispensed with entirely, since the *m* table is arranged for double entry with the arguments, $h =$ height, $t =$ temperature; with $h.\ t.\ m.$ any two being given, the other follows. These new tables give identical results with the others for special cases; they work rapidly in practice; one can compute with accuracy to the one-thousandth of a millimeter, so far as the data are concerned.

The second important group of tables contains the four thermodynamic processes, which take place in the formation of clouds, the unsaturated, the saturated, the freezing and the frozen stages, designated as the α, β, γ, δ, stages, respectively. This subject has been discussed by Ferrel, Hann, Lord Kelvin and others along one line, and by Hertz and von Bezold along another line, though both came to the same conclusion so far as the results are concerned. Hertz has constructed a diagram which graphically deals with the four stages, but it was necessary for him to neglect in part the vapor contents, so that although the divergence is no more than 7^{mm} of pressure between the rigorous and the approximate solutions, yet all the fine accuracy which should pertain to good cloud computations is sacrificed. The direct application of the rigorous formulæ, which are very complex, would require an excessive amount of labor to use them, and they are never utilized by meteorologists. But it seemed to me essential to overcome this obstacle, and accordingly the formulæ were transformed so as to depend upon three arguments, namely, $B.\ t.\ \frac{e}{B}.$ pressure, temperature, and the ratio of the vapor pressure to the barometric pressure. The tables are simple in structure, and involve only moderate interpolations. They work rapidly and have proven to be perfectly satisfactory by use in the actual reductions. The results of this discussion have led to much definite information regarding the physics of clouds in many connections, but only a few of them can be mentioned here.

(1) In the case of air rising from the lower strata to form cumulus clouds there exists a definite level at which saturation takes place, namely the base of the cloud. It is necessary to clearly distinguish between true adiabatic saturation, and the saturation as it takes place in the actual atmosphere. The formulæ of the tables as they stand deal only with adiabatic processes, but in order to apply them to the atmosphere the value of the ratio $\frac{e}{B}$ must be observed at the base of the

cumulus cloud. In the adiabatic process the ratio $\frac{e}{B}$ is constant in the unsaturated stage, that is from the ground to the cloud base, and by two or three easy approximations, after starting with $B.t.e.$ at the ground, we compute $B_s.t_s.e_s$ and the height h_s of saturation. Now the question is, does this computed height h_s agree with the measured height of the cumulus base $h_,$? The result of our work is to show that the observed height $h_,$ is greater than h_s. We must, therefore, determine the values $B_,.t_,.e_,$. at the base of the cloud accurately, and thus find the relation between the adiabatic $\frac{e}{B}$ and the actual $\frac{e_,}{B_,}$. A considerable number of kite ascensions were made in the summer of 1898 by the Weather Bureau, and more than 100 cases occurred in which the $B_k.t_k.c_k.h_k$. were measured by the kite instruments on entering the base of the cloud. These have enabled us to study this important question carefully. It may be stated that four distinct ways have been developed of finding the temperature quite approximately at the cloud base, and hence the vapor tension and the pressure, so that for usual conditions, that is to say excepting the strongly stratified condition which occurs when currents of very different temperatures flow over one another, we can compute the pressure at the height of a mile with an error usually of ±0·02 and always of less than ±0·04 inch, which insures good map drawing at that height. The determination of the divergence of the actual from the adiabatic atmosphere is valuable in its application to several meteorological problems.

(2) It has been assumed that the value of the ratio $\frac{e_,}{B_,}$ obtained for the base of the cumulus cloud holds true throughout the cloud itself, and that in this space the adiabatic laws prevail. The theodolite measurements give the height of the top of the cloud where the process of saturation ends. The saturated or β stage has two cases for consideration, the first being where the top of the cloud is lower than the beginning of the freezing stage, and the second where it passes into or through that stage. We computed the $B'.t'.e'.h'$. at the top of the cloud in the first case, but the corresponding $B_0.t_0.e_0.h_0$ at the bottom of the freezing or γ stage in the second case. Then the thickness of the γ stage with the value of $B^\circ.t^\circ.e^\circ.h^\circ$. at the top of it followed, these being the same as $B_{,,}.t_{,,}.e_{,,}.h_{,,}$. the bottom of the frozen or δ stage. Finally with the observed h'', the top of the cloud, $B.''t.''e''$ were computed. This gives the heights at which the several stages begin and end, and hence the thickness of each stage; thence the gradients of

B.*t.e.* per 100 meters in each stage were computed and tabulated. The work was so arranged as to deal with the mean normal meteorological elements prevailing in each of the 12 months, so that the annual variations in all these quantities were found. Also selected cases, as of the towering cumulo-nimbus clouds, some of which reach to 14,000 meters, were computed throughout. The details are so instructive that several of the computations are reproduced in full. The tops of the lofty cumulo-nimbus give a temperature of $-30°$ or $-40°$ C. in several cases, and of $-59°$ C. in one high cloud. This method of computing the temperature at the top of lofty clouds is a welcome addition to the method of the balloon ascensions for determining the meteorological elements in the highest strata, since the clouds may be considered as accurate sounding gauges. The mean heights of the stages show that the γ stage begins at about $\frac{e'}{B'} = 0{\cdot}0090$ and develops as a wedge-shaped space up to a thickness of about 500 meters for $\frac{e'}{B'} = 0{\cdot}0300$. In this the hail forms, and especially in summer when $t_{,}e_{,}h_{,}$ have large values. I am inclined to think that the stratified appearance of hail stones is due to the fall through a series of these γ spaces alternating with warmer β stages, which may form at different heights in the congested state of the atmosphere accompanying thunder storms, rather than to any vertical orbital circulation such as Ferrel suggested. At every point of these computations the checks are so perfect that we can work accurately to 1 millimeter of pressure and to $0°{\cdot}1$ C. temperature, when the trial approximations are repeated two or three times.

(3) It is a most interesting problem to determine just how much heat must be added to an ideal adiabatic atmosphere to produce the actual atmosphere in the several levels. Two preliminary discussions were required to develop this subject. The first was to determine the normal distribution of temperature as observed each month at all altitudes up to 16,000 meters. For this purpose all the available results of balloon ascensions were collected and discussed by tabular and graphic methods, involving a balanced network of mutually dependent lines, by which the average temperature topography was made up to that elevation. Upon the reliability of these observations and this method of treatment the accuracy of the results required must depend. The second discussion was the determination of the mean heights of the several types of clouds from the stratus to the cirrus in each month of the year. This was found by means of the theodolite observations at Washington, D. C., and from them the region covered annually by each

kind of cloud was carefully mapped out. Beginning with the mean meteorological elements B.*t.e.* at the surface for each month, purely adiabatic values were computed at the required heights; and then the actual state of the atmosphere was computed by using the temperatures derived from the balloon ascensions. Subtracting these values at the same heights, the difference is the quantity of heat required. In integrating $\int\frac{dQ}{T_m}$ I was obliged in this preliminary work to regard T_m as constant, and to take as its value the mean of the adiabatic and the observed temperatures. The formula employed is,

$$\int dQ = Q = T_m \left[\begin{array}{l} \left(\cdot 2374 + \cdot 1512\,\frac{e}{B} + \cdot 0232\,\frac{e^2}{B^2}\right)\log T - \left(\cdot 06858 + \cdot 02592\,\frac{e}{B}\right)\log B \\ -\left(\cdot 2374 + \cdot 1512\,\frac{e}{B} + \cdot 0232\,\frac{e^2}{B^2}\right)\log T_0 + \left(\cdot 06858 + \cdot 02592\,\frac{e}{B}\right)\log B_0 \end{array} \right]$$

the upper terms being the observed and the latter adiabatic. In computing, the dry air and the vapor terms for temperature and for pressure, four in all, were carried through separately; finally the values for each 1000-meter level were interpolated, so that we have in a table the calories required to effect the change from an adiabatic to the actual atmosphere. This is at least a fair effort to elucidate quantitatively the problem of the absorption of heat by the earth's atmosphere. Its interest and importance would justify a special campaign of operations devoted to its more careful study.

The Motions of the Atmosphere.

Besides these mathematical discussions and physical researches, a considerable portion of our labor was expended upon the determination of the stream lines and vectors of motion, which occur throughout anti-cyclonic and cyclonic regions in the United States. The complexity of this subject is so great that it is necessary to refer the reader to the charts of the Report itself for a complete presentation of the result. We had two sources of information to depend upon, namely, the long series of cloud charts which are used in the daily forecasts, but are not published, and the nephoscope observations of the International cloud year. These charts contain blue arrows, showing the direction of motion of the lower or cumulus clouds, and red arrows giving the direction of the upper or cirrus clouds. The United States was divided by me into six areas, the northern Rocky Mountain region, the Lake region, the New England districts, the southern Rocky Mountain region, the west Gulf States and the south Atlantic States, for the purpose of discussion. Then for high and low areas respectively in each district, for winter and also for summer, a set of composite charts was constructed by placing a transparent sheet of paper over a series of the maps, selected to show the same weather type for each district, and tracing in the arrows, from which finally a set of resultant vectors for equal squares was computed by counting the number of compass point directions thus recorded. From 40 to 70 maps were used in making each chart, and the resulting vectors were reduced to an average of 40 vectors in each square. If the frequency of direction is proportional to the prevailing movement of the air, then we obtain a chart of relative motions in all parts of the high and low areas. The result is most instructive, in many respects, of which a few are mentioned. The wind and the lower cloud circulation up to the strato-cumulus type are quite the same in form, though the cloud level is rather more rounded; this movement is very independent of the upper cloud region, which is due eastward, or only a little sinuous over the highs and lows. This is true of ordinary cyclones, but in the case of hurricanes for the South Atlantic States the penetration of the lower circulation into the higher is very pronounced, showing a much deeper disturbance of the air. Cyclones are very thin, only 2 or 3 miles deep, while hurricanes are certainly 5 or 6 miles deep. The anticyclonic and cyclonic areas are hardly to be considered as centers of motion except in the very lowest strata, since currents of air blow directly across them from west to east, even in the cumulus region of the Rocky Mountain districts. It is shown that remarkably long streams of air, as from the North Pacific to the Lake region, and from the Gulf of Mexico to the Lake region, counterflow against each to form the cyclonic circulations. We cannot consider these to be due to vertical convections drawing in these distant masses of air by indraft, since the vertical component ceases at 2 or 3 miles high. Rather the great horizontal convections of the lower strata, caused by the interchange of air between the polar and the tropic zones, produce counter currents at the cyclone centers, which develop vortices discharging upward into the permanent eastward drift. The study of these normal charts of circulation will tend to correct some prevailing erroneous conceptions regarding the structure of cyclones. It will surprise many to see that a strong and warm current in the cumulus region blows directly from the Pacific Ocean eastward across a cold-wave area, showing that cold waves are thin masses of air, hardly one mile thick, produced by surface radiation on the eastern or lea side of the mountains. It is no less remarkable to find that the center of the high areas formed by the isobars drawn from reductions made by the Hazen method, now employed by the Weather Bureau, is often 500 miles distant from that indicated by the vectors of motion. The discrepancy between gradients and wind directions in the mountain districts is already well known, but the problem acquires a special interest from the study of these new charts.

The discussion of the nephoscope observations was very laborious in consequence of the necessity of handling the large mass of figures several times. For this purpose, the area surrounding a center of motion was subdivided into 20 parts, symmetrically disposed on three circles about the center, so that the transference from rectangular to cylindrical coordinates should be simple. The right hand (anti-clockwise) rotation, with positive direction "as the arrow flies," was also adopted. Each observation was located in the proper sub-area according to its own district; each cloud type, at a given mean height, was computed separately; the northern districts were compiled by themselves and the southern by themselves; mean resultants for the vectors were found for each sub-area in 8 levels, and charts of the circulation were constructed by accurately plotting in these vectors. The result shows that a slightly sinuous eastward movement prevails over the high and low areas in the cirrus stratum, gradually deepening as the surface is approached, till in the strato-cumulus the gyratory movement is very marked, and in the cumulus, stratus and wind levels predominant. The actual velocities diminish from 40 meters per second in the cirrus to 5 or 6 m. p. s. at the surface. Next on the theory that the sinuous motion is due to components in composition, the mean rectangular N-S and W-E components were found algebraically, subtracted from the total vectors and the residuals were combined in a secondary system of vectors, which were also transferred to charts. These are the true local gyratory vectors as distinguished from the general motions on the hemisphere. In the cyclone they show an inward radial component from the *bottom to the top*, and nothing outward in the upper strata, as Ferrel's circulation requires. They do not show a maximum velocity at a certain distance from the center with falling off nearer it, as Oberbeck's solution demands, but they increase from the outside up to the center. The components are strongest in the strato-cumulus region and diminish above and below; they show a continuous inflow everywhere together with a strong rotation about the center, such as to cause a true vortex with discharge upwards throughout, the forced upflow being injected into the eastward drift which carries it off, while at the same time the flow is somewhat deflected anti-clockwise. In the anticyclone on the two outer circles 750 and 1250 k. m. radius, there is outflow from top to bottom on all sides; near the center there is inflow at the top, reversal at the middle, and outflow at the bottom, thus causing reversal of gradients in the interior of the anticyclone. The entire system of high and low areas seems to be constructed by the counterflow, chiefly in the cumulus and strato-cumulus levels, of long currents due to horizontal convection, the double action on the pressure, that is the formation of high and low pressures simultaneously in adjacent districts, being referred to the general circulation of the atmosphere, especially the deflecting and centrifugal forces, rather than to local temperature accumulations. The North American Continent is the region where cyclones *form* in large numbers, and Europe-Asia the region where they *dissipate*, so that the violent general circulation over the United States in the lower strata, as compared to that of Europe, is chiefly responsible for this excess in the production, near or in the United States, of the local storms of the northern hemisphere.

A careful study of these vectors in all strata up to 11,000 meters, 7 miles high, reveals the very important fact that there is little disposition to conform to the canal theory of the circulation over the hemisphere, as ordinarily taught, namely consisting of a southward movement in the lower strata from the polar zone towards the tropics, with reversal of the component from east to west at latitude 35°, together with an overflow northward in the higher strata from the tropics towards the poles. While the general circulation conforms to this type in many features, there has always been the greatest difficulty in accounting for the comparatively slow eastward drift in the upper strata of the higher latitudes. Ferrel attributed a large part of the required retardation to the effect of friction, but this is in reality a comparatively small term. Also he stated that the difference in the eastward velocity of the northward and southward moving strata at different elevations represented the expenditure of retardational energy. As a matter of fact the lower strata do not move southward *as a whole*, and our observations do not indicate that the higher strata are vigorously moving northward, because that component is very small. What takes place is this: in each stratum from the surface to the cirrus level about as much air moves north as south, for there are enormous counter currents *passing by each other at the same level, and not over one another at different elevations.* This puts a new aspect on the entire problem of the general circulation. It looks as if the solar radiant energy was absorbed chiefly in the lower strata, and that instead of going the rounds, overflowing above from the tropics, there is developed a continuous leakage in the lower strata, which is observed as our persistent winds from the south. These meet the north winds which flow in obedience to the general circulation, as figured by the form of the land and ocean areas. This escape from the tropical belt diminishes the pressure in low latitudes, which would require to be balanced by an excessively rapid eastward drift. Furthermore, the formation of cyclonic vortices discharging into the eastward drift and distorting it, also retards the eastward velocity. It is along these lines that a more probable explanation of the existing moderate eastward motion may be found than in the Ferrel theory, which has been widely accepted by students.

There is a chapter treating of the barometric diurnal wave and its relation to the magnetic diurnal vectors, as developed in Bulletin No. 21, 1898, together with a comparison of the diurnal components of the motion of the atmosphere locally, which shows some interesting relations. I have been unable, in the time at my disposal, to utilize the new general tables of motion in connection with the vectors just described. Something has been done in the way of a theory of the local cyclone and the tornado, which is promising, though its completion must be postponed to a future day. I have been most efficiently assisted in this work by the faithful labor of Messrs. H. H. Kimball, H. L. Heiskell and R. H. Dean, who have taken great interest in the observations and the computations. The Chief of the Weather Bureau has always placed at our disposal all the resources of the office, and the other officials have uniformly rendered all the aid in their power.

ART. LI.—*The Bacillaria of the Occidental Sea;* by ARTHUR M. EDWARDS, M.D., F.L.S.

IN studying the bacillaria of the Western Coast of North America I have gathered knowledge of them from Alaska to Washington hrough Oregon to California and into Mexico. In Alaska I have not specimens as yet, but I have them from British America and so down. I have also specimens of bacillaria from the region of the Great Plain of Fremont, which I have called the Occidental Sea in my paper published in this Journal for 1891. This extends on the east side of the Rocky Mountains several hundreds of miles, even to the coast of California, where it includes the islands which are Anacapa, Catalina and other islands. For I have bacillaria identical with those on the Great Plain itself, and extends into British America and south into Mexico.

Why it is a sea and not a lake can be judged when I state that it extends at least one thousand miles from north to south, and the same distance from east to west, a larger piece of water than is seen at the present day anywhere, except the Atlantic, Pacific and Indian Oceans. But this sea contained fresh water, as I will show. The boundaries of it are uncertain of course, but they extend, as I have just said, beyond the coast in California away to several hundred miles east of the Rocky Mountains and to the north into British America and south into Mexico. It was formed in what is known as the Eocene period, for this reason: C. King in Vol. I of the Report of the Geological Explorations of the Fortieth Parallel, Washington, 1878, in the Recapitulation of Tertiary Lakes, page 444, gives nine lakes as appearing in the Eocene, Miocene and Pliocene periods. In the Eocene there are, in order, Ute Lake, which takes in the Vermilion Creek group of King and the Wahsatch group of Hayden, which filled the entire Green River Basin for a distance of one hundred and fifty miles, with an east and west expansion of about the same on the 40th parallel. In New Mexico it has been discovered by Marsh and farther south it extended, but how far is uncertain. The deposits belong to the basal Eocene on the borders of the Cretaceous. We can understand why Hector places the marine deposits of New Zealand in the Cretaceous now, although I have several fresh water deposits from that section of country which are found below the marine strata. The deposits of the lake are the beds of the Vermilion Creek group, a series having in the field of the 40th parallel a maximum thickness of 5,000 feet "and carrying besides abundant fresh water mollusca and a few fishes, the characteristic vertebrata fauna of the lowest Eocene." (King, page 486.) The rocks are red sandstones almost vermilion in color, whence the name of the creek, which is a branch of the Green River and of that of the Colorado. So it can be understood why the sea emptied into the south and also why the red sandstone is there without the white bacillarian clay upon it. For the same phenomenon is present in Lake Passaic in New Jersey, where the clayey sand without bacillaria in it is present at Logansville and Pleasant Plains in parallel thin layers, the bacillarian clay having lower specific gravity, being carried down to a lower point and deposited at Hatfield Swamp when the ice barrier melted at and about Paterson.

Next came what King calls the Gosiate Lake, which includes the Green River group of Hayden and the Elka group of King. Along the east base of the Wahsatch Mountains the rocks were tilted up to 14°, leaving the Uinta River, as it was in the Lake period, an island. The rocks in this were mere shales and calcareous clay, with some white fine limestone. Numerous fishes and insects and abundance of fresh water molluscs of the genera Viviparus, Goniobasis and Unio, besides a few beds of lignite, are seen.

Then came the Wahsachie Lake, which includes the Bridges group of King and the Uinta Lake, which includes the Uinta group of Emmons and Marsh. This ends the Eocene. Afterwards the Miocene was laid down, which, in the province of Nevada and Oregon contains the Pah-Ute Lake, which was the Truckee group of King and the John Day group of Marsh, and was contemporaneous with the Sioux Lake, which in the province of the Great Plains includes the White River group of Hayden. The Miocene came also to an end and was followed by the Pliocene: In this came, contemporaneous with the province of the Great Basin, North Park Lake of the North Park group of Hague and Hayden and Cheyenne Lake of the province of the Great Plains and the Niobrara group of Marsh.

At Kausoh Mountains in Nevada the strata were as follows:

1.	Basalt	
2.	Coarse, sandy grit	30 to 40 ft.
3.	Saccharoidal cream-colored limestone carrying fresh water fossils	60 ft.
4.	Marly grits	
5.	Finely-grained friable sandstone	70 ft.
6.	Formation concealed by Quaternary accumulations	100 ft.
7.	Marly grit	50 to 60 ft.
8.	Infusorial silica	200 ft.
9.	Tufa, base not exposed	250 ft.

In the saccharoidal cream-colored limestone are shells of mollusca over the infusorial silica.

Although specimens from this immediate locality have not been examined by me, yet I have some from near by. They are the following, and I have to thank the U. S. Geological Survey for them.

Beaver Lake Beds, Beaver Valley, Nevada.

Amphora ovalis F. T. K.
Cocconeis placentula C. G. E.
Cymbella lanceolata C. G. E.
Denticula thermalis F. T. K.
Encyonema cæspitosum F. T. K.
Fragilaria capitulum D.
Gomphonema olivaceum F. T. K.
" *vitrium* C. G. E.
Melosira undulata F. T. K.
Navicula brebisonii F. T. K.
" *elliptica* F. T. K.
" *oblongea* F. T. K.
" *sphærophora* F. T. K.
Nitzschia sigmoidea C. G. E.
Stephanodiscus carconiensis C. G. E.

Truckee River near Wadsworth, Nevada.

Cocconeis placentula C. G. E.
Cyclotella operculata C. A. A.
Melosira orichalcea F. T. K.

Three miles S. of Helens Springs, Nevada.

Epithema jurgensii C. A. A.
Navicula sphærophora F. T. K.

Three miles S. of Helens Springs, Nevada.

Eunotia gracilis C. G. E.
Crystals of calcium carbonate.

Truckee River S. nr. W. of Wadsworth, Nevada.

Crystals of calcium carbonate.

Indian Reservation, Banks of Truckee River, Nevada.

Amphora ovalis F. T. K.
Cocconeis lineata C. G. E.
" *pediculus* C. G. E.
" *placentula* C. G. E.
Cyclotella (Stephanodiscus) berolinensis C. G. E.
Cymatopleura elliptica A. B.
" *solea* A. B.
Cymbella gastroides F. T. K.
" *lanceolata* C. G. E.
" *maculata* F. T. K.
Encyonema ventricosum F. T. K.
Fragilaria (Staurosira) pectinalis F. C. L. N.
Fragilaria (Staurosira) pinnata C. G. E.
Gomphonema intricatum F. T. K.
Gomphonema mamilla C. G. E.
Hantzschia amphioxys C. G. E.
Melosira undulata F. T. K.
Navicula amphicephala C. G. E.
" *bacillum* C. G. E.
" *maculata* C. G. E.
" *sphærophora* F. T. K.
" *undula* C. G. E.
" *varians* C. G. E.
Roicosphœnia curvata F. T. K.
Surirella striatula T.

Playa Beds in Cañon, South end of Carson Lake.

Amphora ovalis F. T. K.
Cocconeis placentula C. G. E.
Cymbella cymbiformis C. G. E.
“ *lanceolata* C. G. E.
Cyclotella operculata C. A. A.
Epithemia jurgensii C. A. A.
Gomphonema intricatum F. T. K.
Navicula cuspidata F. T. K. forma *Craticule.*
Navicula elliptica F. T. K.
“ *sphærophora* F. T. K.
“ *viridis* C. G. E.
Roicosphœnia curvata F. T. K.
Surirella ovata F. T. K.
“ “ var *Utahensis* A. G.

Walker River associated with Fossil Bones.

Epithemia gibba C. G. E.
Eunotia arcus C. G. E.
Gomphonema olivaceum C. G. E.
Navicula viridis C. G. E.
“ *veneta* F. T. K.
Nitzschia linearis C. A. A.

Mud Flat two m. S. of older Creek Valley, Hot Springs.

Melosira crenulata F. T. K.
Navicula acrosphæria C. G. E.
Navicula viridis C. G. E.

This looks volcanic. It is light, fawn-colored and finely comminuted.

Lower Lake Beds, Rash Creek Section, Mono Lake, California.

Cocconeis placentula C. G. E.
Navicula cuspidata F. T. K. forma *oraticulare.*
Navicula borealis C. G. E.
“ *sphærophora* F. T. K.
Surirella ovata F. T. K.

Four m. N. of Wadsworth Lower Specimen for “Winter Section.”

Cyclotella operculata C. A. A.
Melosira crenulata F. T. K.
Navicula (*Amphipora*) *Navicularis* C. G. E.
Navicula viridis C. G. E.

White Terrace, Marble Butte, Nevada.

Amphora ovalis F. T. K.
Cocconeis placentula C. G. E.
Epithemia jurgensii C. A. A.
Cymatoplea solea A. B.
Cymbella gastroides F. T. K.
Encyonema ventricosum F. T. K.
Navicula sphærophora F. T. K.
“ *rheinhardtii* A. G.
Stephanodiscus berolinensis C. G. E.
Surirella ovata F. T. K.
“ *striatula* F. T. K.

White Terrace, Pyramid Lake, Nevada.

Cocconeis placentula C. G. E.
Cyclotella operculata C. A. A.
Cymbella parva W. S.
Epithemia jurgensii C. A. A.
Gomphonema intricatum F. T. K.
Melosira undulata F. T. K.
“ *crenulata* F. T. K.
Roicosphœnia curvata F. T. K.

WHITE BEDS NEAR FIRST POINT ON THE N. SHORE OF SODA LAKE.

Melosira crenulata F. T. K.

Crystals of calcium carbonate. Pieces of hornblende.

LAKE BED IN EXPOSURE NEAR LEWIS SYMONDS RANCH, MONO LAKE, CALIFORNIA.

Denticula thermalis F. T. K. *Synedra ulna* P. A. C. N.

The rest is sand.

LOWER LAKE BEDS, RUSH CREEK SECTION, MONO LAKE, CALIFORNIA.

Cocconeis placentula C. G. E.	*Navicula borealis* C. G. E.
Navicula cuspidata F. T. K. forma *oraticulare.*	" *sphærophora* F. T. K.
	Surirella ovata F. T. K.

Also two which contained no fossils of any kind.

UPPER LAKE, BEDS S. SHORE OF MONO LAKE, CALIFORNIA. LAKE BONNEVILLE, UTAH.

It will be observed that crystals of calcium carbonate are found in several specimens. These have been deposited when the water which formed the Occidental Sea evaporated, and sodium carbonate is also formed later thrown down as in the soil that is left and in the soda springs which are common all over the Great Plain. Sodium chloride and sodium biborate (borax) are common in waters of the Great Salt Lake, Utah, and Borax Lake, California.

It will be noticed that the forms of the bacillaria are not the same in the specimen as in another. But this is the rule of their distribution. How different are the forms in one spring from another only a few feet apart and in fact in one specimen taken from a river from another taken nearby. The forms can never be the same everywhere in a deposit. That is local distribution.

It will be interesting to note what C. King says of the Eocene lake in the United States Exploration of the Fortieth Parallel, vol. I, 1878. He says on page 360, "As yet the great Eocene lake, whose main deposits are circumscribed by the boundaries of the basin of the Colorado River, is the only one of any considerable geographical area known in the middle Cordillera region. In its earlier stages this lake was coextensive with the rocks of the Vermilion Creek Period, the lowest division of the American lacustrine Eocene." It will be seen that King places the lake in the lowest Eocene where it merges into the Cretaceous, and that he does not make the lake much larger than the Vermilion Creek Period, but this was only on the Fortieth Parallel. He does not take into consideration Mono Lake in California, or the Staked Plain of Texas. These I do, as also Cash Lake in California and other places. Thus I extend the

Eocene Lake into a sea; for its size entitles it to the name of the Occidental Sea.

And now I wish in this connection to say why I place the Subplutonic before the Miocene. That is to say, the Eocene is the Subplutonic which I formerly published. In the opening I shall have to explain why I use the terms Subplutonic and Miocene strata instead of the newer Eocene and Neocene for these layers which I describe before going into the occurrence of one before the other, as I shall thereafter do, and the Subplutonic first. This term I used to designate layers of Diatomaceæ, as they were then called, when I first described them, now about thirty years ago. When I come to study the deposits of Diatomaceæ which were placed in my hands by Mr. George Gibbs, the Geologist of the Northwest Boundary Survey, there were found certain specimens which were associated with eruptions of lava and constituted vast fields on the Columbia River (which were well known) and elsewhere. The lava was always in layers, as was the diatomaceous earth, and they were seen to be distinct from the well known Monterey strata, which had been placed in the Miocene Tertiary by Blake, Bailey and Ehrenberg, and also distinct from the recent strata, which were common everywhere. They were designated Subplutonic, being found beneath lava. This name was given to them not from geological reasons, for their geological position was not found, and the geology of the country where they occurred had not been then discovered. How or when the lava appeared was not ascertained then and was undetermined. These were fresh water strata, or at least the Diatomaceæ were known to inhabit lake and fresh water, and did not grow in brackish marshes or on the shore of the salt ocean.

The Miocene Tertiary, on the contrary, were known from analogy to be marine. That is to say, they contained the same Diatomaceæ which grew in the ocean along the shore on rocks now. They were called Miocene Tertiary, and Blake supposed them to be analogous to the Richmond, Virginia, stratum, which was discovered by Rogers and placed by him in the Miocene Tertiary. And this was supposed to be the same as certain formations in Europe which Lyell had placed there. This was found, as we shall see, not to be so. The Miocene and Pliocene were studied by Dall and Harris and published in the U. S. Geological Survey correlation papers, in 1892. They found the strata in the United States were not exactly analogous or contemporaneous with the Miocene and Pliocene in Europe, or did not contain the same Mollusca, and therefore they erected a period to contain them. They called it the Neocene. So the Richmond, Virginia, and Monterey, California, were marked as the Neocene or Miocene Tertiary strata. They belong to a period which is recent, as I now think.

Newark, N. J.

ART. LII.—*On the Volumetric Estimation of Cerium;* by PHILIP E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale University—XC.]

SOME forty years ago Bunsen* showed that the oxide obtained by the ignition of cerium oxalate might be estimated volumetrically by bringing it in contact with potassium iodide and strong hydrochloric acid and determining the iodine set free. This method may be briefly described by a translation of part of the original article: "The substance to be determined is weighed out in a glass flask of from ten to fifteen cubic centimeters capacity, a few crystals of potassium iodide are added, and the neck of the flask is drawn out by the aid of a blowpipe to a narrow opening. The flask is filled almost to the narrowing of the neck with hydrochloric acid which is free from chlorine or iron chloride, and a little sodium carbonate is added in order to displace the last trace of air by carbon dioxide. The flask is then closed by sealing off the neck in the blowpipe and warmed in a water bath until the cerium compound is completely dissolved, and the quantity of iodine set free is determined by iodometric analysis."

The anhydrous dioxide prepared by the ignition of the oxalate or hydroxide is very slowly acted on by acids, especially when pure.† For this reason the method which Bunsen described has remained the only one adapted to the satisfactory volumetric estimation of the ignited dioxide.

Two portions of the dioxide were prepared by treating the crude cerium chloride in concentrated solution with gaseous hydrochloric acid‡ to saturation to remove the iron. The cerium chloride was then dissolved in water, potassium hydroxide added in excess and chlorine gas passed until the precipitate became distinctly orange in color and the solution gave a strong odor of chlorine.§ This operation was repeated until a portion of the precipitate dissolved in acid showed no didymium absorption bands when examined before the spectroscope. The whole precipitate of the dioxide was then dissolved in hydrochloric acid and the oxalate precipitated by ammonium oxalate in large excess. The precipitated oxalate was then washed thoroughly with hot water until the washings gave no test for hydrochloric or oxalic acids and ignited to the dioxide. Another portion of the dioxide was later prepared by precipitating a solution of pure cerium chloride by means of ammonium oxalate, washing and igniting as described. The dioxide in all three cases was of a light chamois color, and uniform results were obtained from the three portions.

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* Annalen d. Chem. u. Phar., cv, 49.

† Rose: Handbuch der Analytischen Chemie, Band i. 219.

‡ Dennis and Magee: Zeitschr. f. Anorgan Chem., iii, 260.

§ Mosander: Phil. Mag., xxviii, 241; Dennis: Zeit. f. Anorgan. Chem., vii, 252.

A modification of the method of Bunsen—(with G. A. HANFORD and F. J. HALL).

Weighed portions of the pure cerium dioxide were placed in small glass stoppered bottles of about 100^{cm^3} capacity, together with a gram of potassium iodide free from iodate and a few drops of water to dissolve the iodide. A current of carbon dioxide was passed into the bottle for about five minutes to expel the air, 10^{cm^3} of pure strong hydrochloric acid were added, the stopper inserted and the bottle heated gently upon a steam radiator for about one hour until the dioxide dissolved completely and the iodine was set free. After cooling the bottle, to prevent loss of iodine upon removing the stopper, the contents were carefully washed into about 400^{cm^3} of water and titrated with standard sodium thiosulphate to determine the amount of iodine liberated according to the well known reaction

$$2CeO_2 + 8HCl + 2KI = 2CeCl_3 + 2KCl + 4H_2O + I_2.$$

A few blank determinations were carried through in the bottles without the presence of the cerium dioxide to determine the amount of iodine set free under these conditions. The amount obtained was uniformly equal to $0·04^{cm^3}$ of the $\frac{1}{10}$ N iodine solution which was taken as the correction and applied to all the determinations. The results follow in Table I.

TABLE I.

	CeO_2 taken. grm.	CeO_2 found. grm.	Error. grm.
(1)	0·1000	0·0994	0·0006 –
(2)	0·1032	0·1034	0·0002 +
(3)	0·1016	0·1017	0·0001 +
(4)	0·1054	0·1041	0·0013 –
(5)	0·2010	0·2021	0·0011 +
(6)	0·1104	0·1109	0·0005 +
(7)	0·1914	0·1907	0·0007 –
(8)	0·1604	0·1603	0·0001 –
(9)	0·2146	0·2145	0·0001 –
(10)	0·1108	0·1099	0·0009 –
(11)	0·1346	0·1347	0·0001 +
(12)	0·1540	0·1534	0·0006 –
(13)	0·1976	0·1968	0·0008 –
(14)	0·1230	0·1240	0·0010 +
(15)	0·1199	0·1201	0·0003 +
(16)	0·1524	0·1528	0·0004 +
(17)	0·1212	0·1211	0·0001 –
(18)	0·1528	0·1543	0·0015 +

In order to obtain a further check upon the accuracy of the method, portions of the cerium dioxide were weighed out and placed in a distillation apparatus previously employed for similar purposes and described in former articles from this laboratory, viz: a Voit flask, serving as a retort, sealed to the inlet tube of a Drexel wash-bottle, used as a receiver, the outlet tube of which was trapped by sealing on Will and Varrentrapp absorption bulbs. In the retort the cerium dioxide together with 15^{cm^3} of water, 1 gram of potassium iodide and 10^{cm^3} of pure strong hydrochloric acid were placed. In the receiver were 100^{cm^3} of water and 2 to 3 grams of potassium iodide, and in the bulbs a dilute solution of potassium iodide. Before adding the hydrochloric acid a current of carbon dioxide was passed through the apparatus for some minutes. After adding the acid, the liquid was boiled in the current of carbon dioxide* to a volume of 15^{cm^3}, when the free iodine had almost completely left the retort and passed into the receiver, and the apparatus was allowed to cool.

The iodine in the receiver was titrated directly with sodium thiosulphate, and that in the retort after dilution of the residue to about 400^{cm^3}, the later amount seldom exceeding the equivalent of a few drops of $\frac{1}{10}$ N iodine solution.

The results follow in Table II.

Here also blank determinations were made but no correction was found to be necessary.

An attempt early in the work to titrate by an alkaline arsenite the iodine liberated, after neutralizing the hydrochloric acid, brought out some curious results which seem worthy of mention.

TABLE II.

	CeO_2 taken. grm.	CeO_2 found. grm.	Error. grm.
(1)	0·1028	0·1013	0·0015—
(2)	0·2060	0·2055	0·0005—
(3)	0·2014	0·2012	0·0002—
(4)	0·1716	0·1711	0·0005—
(5)	0·0974	0·0972	0·0002—
(6)	0·1600	0·1587	0·0013—
(7)	0·1268	0·1254	0·0014—
(8)	0·1276	0·1268	0·0008—
(9)	0·1620	0·1612	0·0008—
(10)	0·1016	0·1011	0·0005—
(11)	0·1548	0·1543	0·0005—
(12)	0·1352	0·1342	0·0010—

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* The carbon dioxide gas was furnished by a Kipp generator from marble and hydrochloric acid of one-half strength, both of which had been boiled previously to remove all air.

In these experiments the contents of the bottles after the cerium had dissolved were carefully washed into a Drexel wash bottle upon the inlet tube of which was fused a thistle tube with a stop-cock and to the outlet tube a Will and Varrentrapp absorption trap. In the trap a solution of potassium iodide was placed and through the thistle tube a saturated solution of potassium bicarbonate was added to complete neutralization of the acid. Any iodine carried mechanically by the carbon dioxide should be held by the potassium iodide solution in the trap. After neutralization the free iodine was titrated by standard arsenious oxide solution. The results appear in Table III.

TABLE III.

	CeO_2 taken. grm.	CeO_2 found. grm.	Error. grm.	
(1)	0·1000	0·0987	0·0013—	I
(2)	0·1005	0·0981	0·0024—	
(3)	0·1030	0·1009	0·0021—	
(4)	0·1500	0·1475	0·0025—	
(5)	0·1030	0·1005	0·0025—	II
(6)	0·1010	0·0988	0·0022—	
(7)	0·1510	0·1508	0·0002—	
(8)	0·1530	0·1485	0·0045—	
(9)	0·2045	0·2011	0·0034—	
(10)	0·2000	0·1958	0·0042—	
(11)	0·1334	0·1302	0·0032—	III
(12)	0·1354	0·1330	0·0024—	
(13)	0·1312	0·1294	0·0018—	
(14)	0·1308	0·1277	0·0031—	
(15)	0·1060	0·1042	0·0018—	
(16)	0·1602	0·1567	0·0035—	
(17)	0·1504	0·1488	0·0016—	

As will be seen by the table, an average error of about 2 per cent runs through the entire set. The natural conclusion would be that the cerium dioxide contained some impurity; but, as the first, second and third samples, very carefully prepared, gave the same results, it seemed necessary to look elsewhere for an explanation. Two possible causes suggested themselves: first, mechanical loss during the process of neutralization, and second, the possible formation, under the conditions, of iodine chloride, which if formed would in the process of neutralization probably take the form of potassium chloride, iodide, and iodate, and thus some of the originally free iodine would be withdrawn from the amount titrated. To test these theories, portions of the $\frac{1}{10}$ N iodine solution roughly equivalent to the amounts of iodine set free by 0·1 and 0·2 grms. of

CeO_2, were drawn off into bottles previously filled with carbon dioxide, treated with the usual amount of strong hydrochloric acid (10^{cm^3}), and after standing from thirty to forty-five minutes, neutralized and titrated as already described. The results were most interesting and seemed to show a loss of iodine closely equivalent to that shown by the results of Table III, and proportional to the amount of iodine originally present. A few determinations were carried through in the same way except that the neutralization was omitted and dilution and titration with thiosulphate substituted. These showed a loss of iodine well within the limits of such a process. The results follow in Table IV.

TABLE IV.

	Iodine $\frac{1}{10}$ N taken. cm³.	Iodine $\frac{1}{10}$ found. cm³.	Error. cm³.	Equivalent error on CeO_2. grm.
		With Arsenious Oxide.		
(1)	5·22	5·07	0·15—	0·0026—
(2)	5·09	4·97	0·12—	0·0021—
(3)	5·10	4·97	0·13—	0·0022—
(4)	5·66	5·47	0·19—	0·0033—
(5)	5·10	4·97	0·13—	0·0022—
(6)	10·22	9·97	0·25—	0·0043—
(7)	10·21	9·97	0·24—	0·0041—
		With Sodium Thiosulphate.		
(1)	5·	5·01	0·01+	0·0002+
(2)	5·	4·99	0·01—	0·0002—
(3)	10·	10·02	0·02+	0·0003+
(4)	10·08	10·12	0·04+	0·0007+

The action of arsenious oxide upon Cerium Dioxide—(with WM. D. CUTTER).

The fact that cerium dioxide is reduced by hydriodic acid suggested the possibility of the application of arsenious acid in acid solution to the same end according to the reaction

$$4CeO_2 + As_2O_3 = 2Ce_2O_3 + As_2O_5.$$

The extreme difficulty with which the ignited cerium dioxide when pure dissolves in acids has already been mentioned, and for this reason it was found practically impossible to obtain any results by this method. Weighed portions of the dioxide were placed in Erlenmeyer beakers with an excess of a solution of arsenious oxide $\frac{1}{10}$ N, 10^{cm^3} of (1—1) sulphuric acid were added, and the boiling continued until the fuming point of the acid was reached; but even at this point only a partial solution of the dioxide had taken place.

The dark brown powder obtained by igniting the carefully washed oxalates, precipitated in acid solution by treating a solution of crude cerium chloride with ammonium oxalate or oxalate acid, is very fairly soluble in acids. Mengel* has recently shown that this product contains a dioxide of praseodidymium which acts as does cerium dioxide toward reducing agents. This fact makes the results recorded in the treatment of this ignited mixture of oxides of no value analytically, but of interest in the comparative study of the two reducing agents, arsenious oxide and hydriodic acid. Two portions of this mixture of oxides gave the following results, which agree fairly well with those of Mengel.

	Amt. of substance taken. grm.	$CeO_2 + (PdO_2?)$ found. grm.	Calculated on ·1000 grm. grm.
(1)	0·1037	0·0530	0·0511
(2)	0·1034	0·0538	0·0520

The average of these results was taken as a standard —0·0515 grm. CeO_2, etc., to every 0·1000 grm. of material. Three carefully weighed portions of this same material were placed in Erlenmeyer beakers with 10^{cm^3} of $\frac{1}{10}$ N arsenious oxide solution and 10^{cm^3} of dilute (1—4) sulphuric acid and boiled until complete solution had taken place. The liquid was then cooled, neutralized with potassium bicarbonate and titrated with standardizing iodine to determine the amount of arsenious oxide remaining, and from it the amount used in the reduction of the dioxide according to the reaction given above. The results obtained follow.

	Amt. taken. grm.	Amt. CeO_2 found. grm.	CeO_2 calculated for 0·1000 grm. grm.
(1)	0·1005	0·0493	0·0491
(2)	0·1015	0·0494	0·0487
(3)	0·1005	0·0486	0·0484

As will be seen, the results obtained by this method fall about 0·0030 grm. below the standard as obtained by the distillation method, which seems to show that the arsenious oxide does not effect the complete reduction of the cerium dioxide from CeO_2 to Ce_2O_3.

In order to study this point a little more fully and upon the pure dioxide, definite portions of a standard solution of pure cerium chloride were precipitated by ammonia in the presence of hydrogen dioxide and boiled to reduce the CeO_3 formed to the conditions of CeO_2. The precipitated hydrated dioxide was filtered off and carefully washed until the washings gave no indication of hydrogen dioxide. The moist precipitate was then washed into a beaker, one gram of potassium iodide added and 10^{cm^3} of strong HCl. The precipitate dissolved quite readily in the cold and the iodine liberated was determined by standard sodium thiosulphate. The results appear in Table V.

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* Zeitschr. fur Anorgan. Chem., xix, 67.

TABLE V.

	CeO_2 taken. grm.	CeO_2 found. grm.	Error. grm.
(1)	0·1142	0·1140	0·0002 –
(2)	0·1142	0·1147	0·0005 +
(3)	0·1142	0·1152	0·0010 +
(4)	0·1142	0·1159	0·0017 +
(5)	0·1142	0·1152	0·0010 +
(6)	0·1142	0·1156	0·0014 +

Another series of these precipitates prepared in the same way was boiled with a definite amount of arsenious acid in acid solution, as previously described in the case of the ignited dioxide. The results which are recorded in Table VI show, as in the case of the ignited dioxide, an insufficient reduction of the cerium by the arsenious acid.

TABLE VI.

	CeO_2 taken. grm.	CeO_2 found. grm.	Error. grm.
(1)	0·0381	0·0370	0·0011 –
(2)	0·0381	0·0361	0·0020 –
(3)	0·1142	0·1077	0·0064 –
(4)	0·1060	0·1002	0·0058 –

The Estimation of Cerium Oxalate by Potassium Permanganate—

(with LEO A. LYNCH).

Stolba* has stated that cerium oxalate may be estimated volumetrically after the same manner as calcium oxalate by treating the washed precipitate, suspended in warm water, to which a moderate amount of sulphuric acid has been added, by potassium permanganate. As the titration proceeds the precipitate disappears and the end reaction is sharp. He also finds that the permanganate does not oxidize the cerium from the lower to the higher condition. So far as we have been able to discover, no experimental evidence has been presented to prove the correctness of Stolba's statement, and the work to be described was undertaken to furnish such evidence.

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* Sitzungsber. d. kgl. böhm. Gesellsch. d. Wissenschaften v. 4 Juli, 1879; Zeitschr für Anal. Chem, xix, 194.

The solutions used were prepared and standardized as follows: The cerium solutions were made by dissolving 10 grams of pure cerium chloride in one liter of water, and standardized by precipitating measured and weighed portions, in a faintly acid solution, with ammonium oxalate, filtering, washing, igniting, and weighing as the dioxide (CeO_2). A solution of potassium permanganate was prepared and standardized by titration against weighed amounts of ammonium oxalate. A solution of ammonium oxalate was made and its value determined by titrating measured amounts against potassium permanganate. Definite portions of the cerium solution were drawn from a burette and after diluting with water from 100 to 200^{cm^3} a definite amount of ammonium oxalate was added, care being taken to have an excess over the amount necessary, and the whole warmed to insure a more crystalline precipitation.* The precipitate was then filtered off on paper and carefully washed, the filtrate and washings being collected in a liter Erlenmeyer flask and set aside for future use. The precipitate was treated with about 10^{cm^3} of hot (1—4) sulphuric acid, which dissolved it completely, if not at first, by running it through the filter a few times, and the solution and washings were collected in another liter flask. The total volume of liquid was made up to about 500^{cm^3}, warmed to about 70° C. to 80° C. and titrated with potassium permanganate to the appearance of the faint blush of color showing the complete oxidation of the oxalic acid. The filtrate from the cerium oxalate containing the excess of oxalic acid was diluted to 500^{cm^3}, acidified with 10^{cm^3} of dilute (1–4) sulphuric acid, one gram of manganous sulphate added to prevent the interfering action of the free hydrochloric acid upon the estimation of the oxalic acid,† and titrated with potassium permanganate after the same manner as the dissolved precipitate. A definite quantity of ammonium oxalate having been originally taken, it became possible, by subtracting from it the amount obtained, to derive the measure of the oxalate used in the precipitation of the cerium oxalate. By this procedure, it will be observed a check was made upon the results obtained by the titration of the precipitate. In experiments (1) to (6) the cerium oxalate was thrown down in neutral solution, in experiments (7) to (10) in acid solutions. The treatment of the filtrate in experiment (1) was made without the presence of the manganous sulphate. The results recorded in Table VII seem to uphold the statement of Stolba.

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* As shown by the table, the precipitation was sometimes in neutral, sometimes in faintly acid solution.

† Gooch and Peters, this Journal, vol. vii, 461.

TABLE VII.

	Amount taken. Calculated as $CeCl_3$.	Amount found. Calculated as $CeCl_3$. Treatment of precipitate.	Error. Calculated as $CeCl_3$.	Amount found. Calculated as $CeCl_3$. Treatment of filtrate.	Error. Calculated as $CeCl_3$.
(1)	[0·1091	0·1087	0·0004—	0·1023	0·0068—]
(2)	0·1091	0·1103	0·0012+	----	----
(3)	0·1091	0·1087	0·0004—	0·1087	0·0004—
(4)	0·1364	0·1373	0·0009+	0·1391	0·0027+
(5)	0·1364	0·1367	0·0003+	0·1367	0·0003+
(6)	0·2182	0·2202	0·0020+	0·2206	0·0024+
(7)	0·1091	----	----	0·1087	0·0004—
(8)	0·1519	0·1535	0·0016+	0·1535	0·0016+
(9)	0·1364	0·1367	0·0003+	0·1367	0·0003+
(10)	0·2182	0·2183	0·0001+	0·2183	0·0000+

ART. LIII.—*On the Estimation of Thallium as the Chromate;* by PHILIP E. BROWNING and GEORGE P. HUTCHINS.

[Contributions from the Kent Chemical Laboratory of Yale University—XCI.]

CROOKES has shown* that the chromate precipitated by the addition of potassium dichromate to an alkaline solution of a thallous salt has the constitution of a neutral salt and is very insoluble in water—100 parts of water at 100° C. dissolving about 0·2 parts and at 60° C. about 0·03 parts. He has also made use of this reaction† to effect a rough separation of thallium from cadmium.

The object of this paper is to describe some work directed toward a study of the application of this reaction to the gravimetric estimation of thallium and the best conditions under which to effect the precipitation. For the work a solution of thallous nitrate was made by dissolving 10 grms. in water making up to a liter. The standard was determined by taking measured and weighed portions from a burette, precipitating with a slight excess of potassium iodide, agitating to bring about a good separation of the thallous iodide, and allowing to stand until the supernatant liquid was clear. The iodide was then filtered off upon an asbestos felt contained in a perforated platinum crucible, the whole having been previously ignited and weighed, washed with a mixture of alcohol and water, dried over a low flame and weighed to a constant weight. The filtrate, which together with the washings seldom amounted to more than 50^{cm^3}, was evaporated to dryness on a water bath, a few drops of water added and thus the small amount of thallous iodide which had been dissolved recovered. This small insoluble residue, which seldom amounted to one milligram in weight, was filtered off, washed and weighed as previously described. Baubigny‡ has shown this method to give very satisfactory results, and the uniformity of our determinations certainly confirms his statements.

For convenience in the calculations of results to be described later, a solution of potassium dichromate of definite strength was made. Portions of the thallium solution were drawn from a burette into test tubes of about 100^{cm^3} capacity and weighed as a check on the burette reading. The solution was heated to about 70° C. to 80° C. and a few drops of ammonia or potassium carbonate solution added to distinct alkalinity. A definite amount of the potassium dichromate in solution was delivered from a burette, care being taken to have an excess, and the contents agitated to bring about a good separation of the precipitated chromate. After the precipitate had completely settled out and the solution had become cold the chromate was filtered upon asbestos, as described above, dried over a low flame and weighed to a constant weight. The filtrates from several determinations were evaporated to a small volume and in one or two cases a residue amounting to a few tenths of a milligram was obtained, but no appreciable quantity of dissolved chromate was thus recovered. It was found that when the precipitation was made in the cold the chromate did not flock well, but remained partly in a finely divided condition which would run through the felt and require repeated filtration. The addition of ammonium nitrate before precipitation prevented this largely, even in the cold, but the best results were obtained by warming the solution before precipitation and using potassium carbonate rather than ammonium hydroxide. The results follow in Table I.

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* Chem. News, viii, 255.

† Chem. News, vii, 145.

‡ Chem. News, lxiv, 239.

TABLE I.

	$TlNO_3$ taken. Calculated as Tl_2O. grm.	Tl_2CrO_4 found. Calculated as Tl_2O. grm.	Error. Calculated as Tl_2O. grm.
(1)	0·0796	0·0791	0·0005 —
(2)	0·0792	0·0788	0·0004 —
(3)	0·0792	0·0786	0·0006 —
(4)	0·1188	0·1177	0·0011 —
(5)	0·1192	0·1186	0·0006 —
(6)	0·1185	0·1178	0·0007 —
(7)	0·1190	0·1185	0·0005 —
(8)	0·1189	0·1183	0·0006 —
(9)	0·1196	0·2000	0 0004 +
(10)	0·1196	0·2005	0·0009 +
(11)	0·1173	0·1173	0·0000
(12)	0·1171	0·1163	0·0008 —

An attempt was made to estimate the thallium volumetrically by determining the amount of chromate in the filtrate from the thallous chromate, and by difference (the potassium dichromate originally added being known) the amount combined with the thallium in the precipitate. The method used to determine the standard of the dichromate solutions and also the chromate remaining in the filtrate was described by one of us in a previous paper from this laboratory.* According to this procedure the filtrate from the thallous chromate containing the excess of alkali chromate was acidified with sulphuric acid, a definite amount of a solution of arsenious oxide, previously standardized, was added and the whole was allowed to stand a few moments until the change from the yellow to the bluish green showed the complete reduction of the chromic acid. Potassium bicarbonate was added to distinct alkaline reaction and the arsenious oxide remaining was determined by titration with standard iodine solution. The amount of the arsenious oxide oxidized is of course the measure of the chromate in the solution. The amount of chromate in the original solution used being known, by subtracting the amount thus determined in the filtrate, the chromate in combination with the thallium may be readily found, and from it the thallium estimated. Filtrates from certain precipitates, of which the determinations are given in Table I, were treated in this way, and the results, indicated by corresponding numbers, follow in Table II.

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* This Journal, vol. i, 35, 1896.

TABLE II.

	$TlNO_3$ taken. Calculated as Tl_2O. grm.	Tl_2CrO_4 found. Calculated as Tl_2O. grm.	Error. Calculated as Tl_2O. grm.
(5)	0·1192	0·1198	0·0006 +
(8)	0·1189	0·1205	0·0016 +
(9)	0·1196	0·1180	0·0016 −
(10)	0·1196	0·1192	0·0004 −
(11)	0·1173	0·1182	0·0009 +
(12)	0·1171	0·1190	0·0019 +

The method cannot be very accurate on account of the high molecular weight of thallium oxide as compared with that of the chromic acid determined, but the results check fairly well with the gravimetric method.

July, 1899.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Existence of masses smaller than atoms.*—At the late meeting of the British Association at Dover, Prof. J. J. THOMSON read an important paper on this subject. He considers that electrification consists in the removal from the atom of a small corpuscle with which the negative charge is associated. The remaining large portion of the mass is positively charged. This view is supported by Prout's hypothesis that the mass of an atom is not invariable and by the evidence derived by Lockyer and others from spectroscopic observations.—*Nature,* Oct. 12, 1899. J. T.

2. *Dispersion of the Cathode Rays by magnetic force.*—M. BIRKELAND has observed that when a narrow beam of cathode rays produced by an induction coil is deflected by a magnetic field, that certain rays are deflected more than others, and he has given to this effect the name of the magnetic spectrum. R. J. STRUTT of Trinity College, Cambridge, has examined this subject and by the use of a storage battery of 800 cells shows that the formation of the magnetic spectrum is due to a peculiarity of the induction coil. The cathode rays produced by a battery are homogeneous.—*Phil. Mag.*, Nov., 1899, pp. 478–480. J. T.

3. *A new Radio-active Substance.*—M. A. DEBIERNE has isolated from pitchblende a substance which emits rays which are 100,000 times stronger than those given off by uranium. They render gases capable of discharging electricity, excite the phosphorescence of barium platino-cyanide and affect photographic plates.—*Comptes Rendus,* Oct. 16. J. T.

4. *Radio-active effect of Barium Salts and Polonium.*—In the course of a paper on these subjects, F. GIESEL, the author, states that a surprising difference exists in regard to the penetrating power of the rays of radium and those of polonium. While the rays from radium penetrate fairly well a silver thaler, the rays from polonium, although more intense, are absorbed by thinner metallic plates. The shadow of the hand and of metallic objects thrown by the polonium rays on a fluorescent screen are stronger in contrast than when produced by the radium rays.—*Wied. Ann.*, No. 9, 1899, pp. 91–94. J. T.

5. *Becquerel rays.*—These rays seem to be Röntgen rays of feeble intensity; in common with them they act upon photographic plates, dissipate electric charges, and produce luminescence. The intensity of the rays appears to be kept up without apparent consumption of energy. J. ELSTER and H. GEITEL have studied the behavior of these rays, which were produced from a piece of Joachimsthal pitchblende of 300 grams weight, 7^{cm} long, 5^{cm} broad and $1{\cdot}5^{cm}$ thick. They appear to be uninfluenced by expo-

sure of the substance to cathode rays, to sunlight, or to heat. They were not deflected by a magnetic field. Their power of rendering air a better conductor of electricity was lessened in such a field.— *Wied. Ann.*, No. 9, 1899, pp. 83–90. J. T.

6. *Magnetizing constants of inorganic substances.* — **STEFAN MEYER** has made an extended study of the behavior of a large number of inorganic substances in the magnetic field and gives tabulated results. One of the most interesting facts he states is in regard to erbium. In the combination Er_2O_3 it is four times stronger than Fe_2O_3. If in the pure metallic state it were as magnetic as it is in the state of oxide, one could reduce the weight of dynamos one-sixth and still obtain the same output as when iron is employed.— *Wied. Ann.*, No. 9, 1899, pp. 236–263. J. T.

7. *The Color Sensations in Terms of Luminosity;* by **W. DE W. ABNEY**. (Abstract.)—This paper deals with a determination of the color sensations based on the Young theory by means of measures of the luminosity of the three different color components in a mixed light which matches white. At the red end of the spectrum there is only one color extending to near C, and there is no mixture of other colors which will match it, however selected. At the violet end of the spectrum, from the extreme violet to near G, the same homogeneity of light exists, but it is apparently due to the stimulation of two sensations, a red and a blue sensation, the latter never being felt unmixed with any other. Having ascertained this, it remained to find that place in the spectrum where the blue sensation was to be found unmixed with any other sensation except white. By trial it was found that close to the blue lithium line this was the case, and that a mixture of this color and pure red sensation gave the violet of the spectrum when the latter was mixed with a certain quantity of white. The red and blue sensation being located, it remained to find the green sensation. The complementary color to the red in the spectrum gave a position in which the green and blue sensations were present in the right proportions to make white, and a point nearer the red gave a point in which the red and blue sensations were present in such proportions as found in white, but there was an excess of green sensation. By preliminary trials this point was found. The position in the spectrum of the yellow color complementary to the violet was also found. The color of bichromate of potash was matched by using a pure red and the last-named green. To make the match, white had to be added to the bichromate color. A certain small percentage of white was found to exist in the light transmitted through a bichromate solution with which the match was made, and this percentage and the added white being deducted from the green used, gave the luminosity of the pure green sensation existing in the spectrum color which matched the bichromate. Knowing the percentage composition in luminosity of the two sensations at this point, the luminosity of the three sensations in white was determined by matching the bichromate color with the yellow

(complementary to the violet) and the pure red color sensation. From this equation and from the sensation equation of the bichromate color already found, the composition of the yellow was determined. By matching white with a mixture of the yellow and the violet, the sensation equation to white was determined. The other colors of the spectrum were then used in forming white, and from their luminosity equations their percentage composition in sensations were calculated. The percentage curves are shown. The results so obtained were applied to various spectrum luminosity curves, and the sensation curves obtained. The areas of these curves were found, and the ordinates of the green and violet curves increased, so that both their areas were respectively equal to that of the red. This gave three new curves in which the sensations to form white were shown by equal ordinates.

A comparison of the points in the spectrum where the curves cut one another, and of those found by the red and green blind as matching white, show that the two sets are identical, as they should be. The curves of Koenig, drawn on the same supposition, are called attention to, and the difference between his and the new determination pointed out.

The red below the red lithium line, as already pointed out, excites but one (the red) sensation, whilst the green sensation is felt in greatest purity at λ 5140, and the blue at λ 4580, as at these points they are mixed only with the sensation of white, the white being of that whiteness which is seen outside the color fields.—*Proc. Roy. Soc.*, No. 419.

II. GEOLOGY AND MINERALOGY.

1. *Geology of the Aspen Mining District, Colorado;* by JOSIAH EDWARD SPURR; pp. 250, pl. liii, with atlas containing sheets xxx, 1898, U. S. Geological Survey, C. D. Walcott, Director. Monograph XXXI.—The detailed study of the Aspen District, made by Mr. Spurr, has resulted in an admirable solution of a difficult geological problem. The monograph, while it is primarily intended for those directly interested in mining, contains much that is of interest from a scientific point of view, and is a valuable addition to the literature of Mining Geology. The contents are briefly as follows:

Introduction, by Mr. S. F. Emmons, geologist in charge.
Chapter I. Description of rock formation.
" II. General descriptive geology.
" III. Detailed description of various mines and productive localities.
" IV. Chemical geology.
" V. Surface changes since ore deposition. Appendix.

The accompanying atlas with its carefully prepared sheets, and the many plates in the book itself illustrate clearly the structure of the region. The following will serve as a brief outline of its geology: the intrusion of two distinct sheets of igneous rock into sedimentary beds of great thickness, representing deposits from the Archean through Cretaceous times; a general folding of the region and severe local disturbances in the vicinity immediately south of the city of Aspen, due, probably, to the pushing upward of a deeply buried igneous mass, resulted in a profound and complicated series of faults. The lines of faulting have since served as channels along which, widespread mineralization and chemical changes have been effected by mineralized waters. The ores, which are chiefly sulphides of lead and zinc carrying silver and associated with a gangue of barite, quartz, and dolomite, are commonly found at the crossing of two faults, one dipping steeply, the other nearly horizontal; and the theory is advanced that, ascending, mineral-bearing solutions in one channel meeting those of a different nature in another, caused a precipitation of ores at the contact. Since ore deposition, erosion has carried off the overlying strata to an amount estimated at 15,000 ft. and exposed the ore-bearing beds. C. H. W.

2. *Iowa Geological Survey, Vol. IX.* Annual Report, 1898, with accompanying papers, by SAMUEL CALVIN and H. F. BAIN, pp. 11–572, plates i–xiii, 1899.—The great bulk of this volume is devoted to the elaboration of the details of geology by counties. Discussions of particular interest are those on the Pleistocene distribution and loess, as found in Udden's report on Muscatine County, and in Norton's report on Scott County, and in Bain's discussion of the Pleistocene in Carroll County. Also of interest are Udden's study of the range of species in the Devonian beds of Muscatine County; and Norton's facts on the contents of Devonian faunas in Scott County. The closing paper is by Mosnat on the Artesian wells of the Belle Plaine area. By means of the well records valuable details of underground structures are developed. W.

3. *Geological Survey of Michigan*, vol. vi, 1893–1897. L. L. Hubbard, State Geologist.—This volume consists of three parts. The first by Dr. A. C. LANE, of 281 pp., is a geological report on Isle Royale. The structure of the island is thoroughly described and discussed with special reference to the copper mining industry. The petrography of the igneous rocks is also fully entered into. In the same thorough way Dr. HUBBARD has given an account of Keweenaw Point in Part II, containing 155 pages. These reports are fully illustrated with maps, sections, diagrams and photographs. In an appendix Dr. CHAS. PALACHE gives the results of a detailed crystallographic study of the calcite crystals from the copper mines of the Lake Superior region, so long celebrated for the beauty and perfection of their crystallization. L. V. P.

4. *Report on Gypsum and Gypsum Cement Plasters;* by G. P. GRIMSLEY and E. H. S. BAILEY, under the direction and with the assistance of Erasmus Haworth. Vol. V of the University Geological Survey of Kansas; pp. 183, plates xxx. Topeka,

1899.—Some notes were given in the last number (p. 396) of recent work on the salt deposits of Kansas. The present interesting volume, published at about the same time, takes up the subject of gypsum and describes with all necessary fullness the occurrence of the important deposits in the State, with also the technological and chemical aspects of the subject.

5. *Ueber Strandbildungen des Litorinameeres auf der Insel Mantsinsaari;* by J. Ailio (Bull. Commission géologique de la Finlande, 1898, pp. 41).—Of recent years the Finnish geologists have been carefully studying the ancient elevated sea margins of northern Europe. The present paper is devoted to those of an island in the great Ladoga Lake. Many interesting features regarding these littoral formations are described and there is an excellent map in colors showing the retrogression of the waters.

L. V. P.

6. *Ueber eine Archäische sedimentformation im südwestlichen Finland;* von J. J. Sederholm (Bull. Commission géologique de la Finlande, No. 6, pp. 254, 1899).—The object of the author in this paper is to show that a series of metamorphic, schistose and crystalline rocks were originally true normal sediments which had been laid down in water or were of eolian origin, interbedded with effusive lava flows, and that they had belonged to a Pre-cambrian folded, mountain complex. The structure so far as possible, and especially the petrology, are very carefully worked out. It is a valuable contribution to the general knowledge of the subject of folded and metamorphosed rocks as well as of interest in its local application. In addition to cuts, plates and maps, it contains an excellent geological map of Finland.

L. V. P.

7. *A Study of the Peat Bogs of Finland and their Fossil Quaternary Flora;* by Gunnar Andersson. (Bulletin de la Commission géologique de la Finlande, No. 8, Studier öfver Finlands Torfmossar och Fossile Kvartärflora. Helsingfors, Dec., 1898.)—This study includes 21 text figures and 216 figures in four plates. It is based on a seven weeks examination of the Finland bogs, which, owing to their great extent, the writer considers to have been barely sufficient time. A number of sections are given, the uniform absence of shelly or marl layers being noticeable.

As in western Scandinavia and on the Baltic side of Sweden three periods of elevation and subsidence are noted, marked by *Yoldia*, *Ancylus*, and *Litorina* horizons. With the exception of isolated fish bones, remains of vertebrates were not found, presumably because of the action of humus acids and almost complete absence of lime in these Finnish bogs. The earlier bush flora following the glacial retreat is still being studied. No birch period, as sometimes proposed, was found to be present. An early well-marked pine flora appeared previous to the *Ancylus* horizon. An elm flora near the close of the pine flora is doubtful. Three plants not now found in northern Europe, *Ceratophyllum sub-*

mersum, *Platydema violacea*, and *Trapa natans*, together with the southerly retreat of other plants, indicate a distinctly warmer climate for the post-*Litorina* oak period following the pine flora. The decline of the oak period is supposed to have been coeval with early man, the present being marked by fir forests in the south, and pine in the north. G. R. W.

8. *La Géologie expérimentale;* par Stanilas Meunier. 8°, pp. 311. Paris, 1899 (F. Alcan).—In this work the author has discussed in a popular manner a number of common geological phenomena as well as some of those more abstruse, and gives the details of rather simple experiments by which these may be imitated and in many cases explained. The work is illustrated by cuts of apparatus. The teacher of geology will find it to contain many suggestive hints. L. V. P.

9. *Brief notices of some recently described minerals.*—A paper by the late Prof. Arzruni and K. Thaddéeff, completed and edited by A. Dannenberg (Zeitschr. f. Kryst., xxxi, 229) contains descriptions of the following three new species from Chili.

Arzrunite occurs in drusy crystalline crusts and rarely in distinct small prismatic crystals. These are hexagonal in aspect but are shown optically to belong to the orthorhombic system; the prismatic angle varies but little from 60°. The color is blue or bluish green with strong pleochroism. Two analyses by Thaddéeff, both on very small quantities, gave the following results:

	SO_3	Cl	PbO	CuO	SiO_2	Fe_2O_3	CaO	ZnO	H_2O
1.	8·07	14·39	31·41	21·39	13·60	0·70	1·70	undet.	undet.
2.	13·06	9·46	33·38	14·54	8·88	1·81	1·87	4·08	11·01=98·09

These analyses vary widely, but by assuming the presence of various impurities, namely, quartz (SiO_2), limonite ($2Fe_2O_3.3H_2O$), gypsum ($CaSO_4+2H_2O$) and goslarite ($ZnSO_4+7H_2O$), a ratio is obtained for the pure mineral corresponding to a double salt of basic lead sulphate and basic copper chloride. The final formula obtained is $PbO.PbSO_4+3(CuCl_2.H_2O)+Cu(OH)_2$. The exact locality is in the mine Buena Esperanza, Challacollo, Tarapaca, Chili.

Stelznerite occurs in loose crystalline masses and, implanted upon them, in fine green transparent prismatic crystals. These resemble brochantite closely, to which species the new mineral is allied chemically. The crystals belong to the orthorhombic system, the prismatic angle being 53° 28′. The specific gravity is 3·884. An analysis gave Thaddéeff:

SO_3	CuO	H_2O	Fe_2O_3	CaO	insol.	
22·40	67·08	10·22	0·34	0·06	0·44	100·54

For this the formula calculated is $CuSO_4.2Cu(OH)_2$. The locality is Remolinos, Vallinar, Chili.

Rafaëlite forms a crystalline incrustation on galena, quartz and celestite. The crystal needles are transparent and of a violet-red color and metallic-adamantine luster. They belong to the monoclinic system and show considerable complexity of form, the prismatic zone being highly developed. A qualitative analysis showed the mineral to be a lead oxychloride, but the material was too scanty to allow of an analysis. Locality, the San Rafael mine, Sierra Gorda, Chili.*

The same authors also give a new examination of utabite in distinct crystals; the formula deduced is $Fe_2O_3.SO_3.2H_2O$. They further describe a basic bismuth carbonate from Schneeberg which seems to be new, having the composition, $5Bi_2O_3.H_2O.CO_2$.

Loranskite is a new tantalate first investigated by M. Melnikow and named by him after A. Loranski. It occurs at Imbilax near Pikäranta, Finland, in massive form in quartz veins. It is optically isotropic with conchoidal fracture; hardness about 5 and specific gravity nearly 4·6; color black and streak greenish gray. An analysis by P. Nikolajew gave :

	Ta_2O_5	ZrO_2	Y_2O_3	Fe_2O_3	CeO	CaO	Ign.	
G.=4·162	47·0	20·0	10·0	4·0	3·0	3·3	8·15	=95·45

A small amount of sulphur and traces of titanium and manganese were not determined.—*Zeitschr. f. Kryst.*, xxxi, 505.

Stokesite. This new mineral, named in honor of the distinguished physicist, Sir George G. Stokes, is described by A. Hutchinson from a single crystal in the Cambridge Mineralogical Museum. The crystal is 10^{mm} in length and belongs to the orthorhombic system; it shows the forms *b* (010) and *v* (121). Cleavage is perfect parallel to *b* and also good parallel to a prism taken as 110. The axial ratio deduced is $\breve{a} : \bar{b} : c = 0{\cdot}3479 : 1 : 0{\cdot}8117$ (the author gives no angles). The physical characters are as follows: fracture conchoidal; hardness about 6 to 6·5; specific gravity 3·185; luster vitreous, but pearly on *b*; colorless; optically positive with the axial plane parallel to *b* and the bisectrix normal to 001.

A partial chemical examination has led to the conclusion that it is a hydrated silicate of sodium and calcium with about 6 p. c. of tin dioxide supposed to replace part of the silica.—*Phil. Mag.*, November, 1899, p. 480.

Von Diestite. M. Cumenge has recently described (Bull. Soc. Min., xxii, 25, 1896) a telluride of silver and bismuth from Colorado, discovered by the mining director Von Diest. It occurs in veins with copper minerals and auriferous pyrite in the Hamilton and Little Gerald mines on the slopes of the Sierra Blanca. An analysis by Knight has given the following results:

Te	Bi	Ag	Au	Pb	S	insol.	
34·60	16·31	40·25	4·30	2·25	0·54	0·54	= 98·79

10. *A Preliminary Report on a Part of the Clays of Georgia;* by George E. Ladd, Assistant Geologist. Bulletin No. 6–A, Geological Survey of Georgia. W. S. Yeates, State Geologist. Atlanta, Georgia, 1898.—The latest addition to the valuable series

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* In the October number of the *Mineralogical Magazine*, received after the above was in type, it is shown by G. F. Herbert Smith that rafaelite is identical with paralaurionite (ibid., April 1899).

of bulletins published by the Georgia Survey is this pamphlet on the clays. It is a subject of great practical interest, and the information brought together here will doubtless prove interesting to all concerned. The opening pages give an account of the properties of clays, their behavior with respect to water, heat, etc., and also methods of testing them. Following this is an account of some of the special localities at which valuable clays occur, particularly in the southern part of the state, with the results of chemical analyses and physical tests.

11. *A proposed International Journal of Petrology.* (Communicated.)—The Committee appointed by the Seventh International Congress of Geologists to consider plans for the establishment of an International Journal of Petrology has chosen Professor F. Becke of Vienna, well known as the editor of Tschermak's Mittheilungen, President of the Committee, and has taken the first steps toward the organization of such a journal. It has been proposed that articles appearing in it shall be printed in French, German or English at the option of the author.

While primarily intended for the publication of reviews and abstracts of all petrographical papers wherever published, it is suggested that it may include also articles which shall appear in it for the first time. The carrying out of this must depend upon the financial support the journal receives.

The journal is to be managed by a committee appointed by the International Congress of Geologists, the committee to select an editor who shall have two assistants; the editor and assistants to receive salaries for their services.

The desirability of having one source, thoroughly up to date, to which to turn for information concerning all matters published on petrology is self-evident to all attempting to keep abreast with the rapid advance of this science. One has only to observe what a great impulse to the science of mineralogy has been given by the establishment of Groth's Zeitschrift fur Krystallographie, to be convinced of the usefulness and convenience of such a journal.

The necessity of forecasting as correctly as possible the financial support obtainable for such a journal has suggested to the American members of the committee the plan of calling attention to the enterprise and of inviting all interested in its success to communicate to either of them such suggestions or information as may aid in estimating the amount of annual subscriptions or contributions that may be obtained from this country.

It is expected that the chief support will come from individual subscriptions and from university and public libraries, but it may be possible to obtain assistance, in the first years of the undertaking at least, from other sources.

J. P. Iddings,
L. V. Pirsson,
Members of the Committee for America.

III. Botany and Zoology.

1. *A Text-book of Plant Diseases, caused by Cryptogamic Parasites;* by GEORGE MARSEE, F.L.S., Principal Assistant (Cryptogams), Royal Herbarium, Kew; pp. xii+458, with 92 figures in text. London, 1899 (Duckworth & Co.); New York (The Macmillan Co.).—This account of plant-diseases is designed chiefly for farmers, gardeners and foresters who have little knowledge of cryptogamic botany and little time available for study. It is therefore written in a semi-popular style, but contains numerous references to literature for those who may desire to investigate particular diseases more thoroughly. In the short introductory portion, the general characteristics of Fungi and of the less important parasites are briefly described, and attention is directed to the most satisfactory fungicides and to the methods in which they should be applied. The greater part of the book is taken up with the detailed descriptions of over two hundred diseases. In each case the appearance of the affected portion of the host-plant is described, together with the gross and minute structure of the parasite, and particular directions are given for preventing the spread of the disease. The more important diseases are fully illustrated by figures. At the close of the volumes the various Fungi treated are arranged in order and briefly redescribed in scientific terms. The frequent mention made of the work done in the United States by botanists connected with the Department of Agriculture is worthy of note. A. W. E.

2. *Observations on the Colors of Flowers;* by E. WILLIAMS HERVEY; pp. 105, 4 illustrations in text. New Bedford, 1899 (E. Anthony & Sons).—The subject-matter treated in this little pamphlet is divided into three parts. In the first, entitled "sequence of color," the author brings forward numerous observations to show that there are many exceptions to the sequence described by Grant Allen, who claimed that the primitive color of flowers was yellow, becoming white, red, purple, and, ultimately, violet or blue, as the flowers advanced in complexity. In the second part, entitled "honey-guides," doubt is thrown upon the common interpretation of these interesting flower-markings, and it is claimed that they result simply from the local irritation caused by insect-visitors in their search for nectar and that the latter are not guided by them at all. In the third part the theory elaborated by Professor Müller that flower-colors are produced through the selective agency of insects, is criticised.

A. W. E.

3. *Text-book of the Embryology of Invertebrates, from the German of* E. KORSCHELT and K. HEIDER; 3 vols. 8°. New York (The Macmillan Co.). Vol. I, *Porifera, Cnidaria, Ctenophora, Vermes, Enteropneusta, Echinodermata*, translated by EDWARD L. MARK and W. McM. WOODWORTH, pp. 500, 1895. Vols. II, *Phoronidea, Bryozoa, Ectoprocta, Brachiopoda, Entoprocta, Crustacea, Palæostraca*, and III, *Arachnida, Pentasto-*

midæ, *Pantopoda*, *Tardigrada*, *Onychophora*, *Myriopoda*, *Insecta*, translated by MATILDA BERNARD and revised by MARTIN F. WOODWARD; pp. 491 and 453, 1899.—Professors Korschelt and Heider's great work is one of the most valuable, if not the most valuable, of all the biological text-books which have appeared in the present decade. All English-speaking students of biology are deeply indebted to the several translators for attempting their part of the work, as well as for the painstaking labor they have bestowed upon it. Nothing can give a better idea of the recent progress of invertebrate embryology than a comparison of this work with the thin first volume of Balfour's Comparative Embryology which appeared in 1880. The vast mass of literature which appeared during the ten years from the time of Balfour's work was carefully reviewed by Korschelt and Heider and condensed into their work, which gives full citations for each investigator's contribution to the subject in hand, and thus becomes a complete guide to the literature of the period. Some idea of the extent of this literature is given by the indices to authors, the index in each of the three volumes of the translation containing 250, or more, names.

Many additions have been made to the original text both by the authors and the translators, so that the work is in great measure brought down to the time of publication. This is especially true of the bibliographical lists which include the recent literature very fully. The translation throughout, like that of Prof. Mark's admirable translation of Hertwig's classical Text-book of the Embryology of Man and Mammals, cannot be too highly praised. It is clear and accurate without the use of German words or German idioms. In rendering Anlage into English Prof. Mark introduced the word *fundament*, which was used throughout the first volume. In the subsequent volumes Dr. Woodward has substituted the much abused word *rudiment*, returning to the primary meaning of the word which Darwin and most recent biologists have unfortunately misapplied to vestigial structures. This appears to the writer a reasonable substitute for fundament, primordium, proton, etc., as well as for the un-English Anlage, and a possible solution of a much vexed question, but it is scarcely to be expected that it will be generally accepted. The mechanical execution of the work is excellent, but the change in the size of the page after the first volume appears unfortunate.

The translators of the first volume were unable to continue the work and there was a tantalizing delay in the appearance of the second volume, which, however, was very quickly followed by the third, and in the preface to this Dr. Woodward states that he hopes to publish the fourth and concluding volume, containing the Mollusca, Ascidia, and Cephalopoda, at the end of the year.

S. I. S.

4. *A Text-book of Vertebrate Zoology;* by J. S. KINGSLEY. 8°, pp. 446. New York, 1899 (Henry Holt and Co.).—This is an advanced text-book intended to follow and supplement laboratory

work and lectures. It is divided into two nearly equal parts, an outline of the morphology of vertebrates based on embryology, and an outline of a classification. The first part covers essentially the same ground as Wiedersheim's Elements of the Comparative Anatomy of Vertebrates but with a very different arrangement, the morphology of the organs being taken up under entodermal, ectodermal, mesothelial, and mesenchymatous structures. This is followed by brief accounts of the segmentation of the head, the early history of the ovum, and the origin of the vertebrates. In the second part, fossil forms are included, the classification is carried as far as orders, and the birds are ranked as a single class of four orders. A large number of the 378 well chosen illustrations are original. The large proportion of diagramatic figures is a valuable feature of the work, which includes an important field not well covered by any other text-book.

S. I. S.

5. *Insects, their Structure and Life;* by GEORGE H. CARPENTER. 8°, pp. 416. London, 1899 (J. M. Dent and Co.).—This little treatise, very modestly called by the author "A Primer of Entomology," is a condensed sketch of the whole subject of which it treats, written in simple, untechnical language, and very fully illustrated with well selected figures. The subjects of the six chapters are: structure, life-history, classification, orders of insects, insects and their surroundings, and the pedigree of insects. While of necessity a compilation, the vast mass of material used is so thoroughly digested and up to date that the result is very satisfactory. The references to the literature at the end of the volume are very full for a work of this kind and make a good guide to the more important recent work in entomology. There is a good index and the paper and printing are excellent.

S. I. S.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *November Meteors of 1899.*—It appears to be almost certain that the earth at this crossing of the orbit of the Leonids has passed through a portion of the stream of comparatively small density. Press reports extending from India, where WEISS of Vienna had stationed himself, to California agree in describing the shower as but a slight one and the most favored localities seem to have had a display of Leonids inferior to that of an average August shower.

Two obvious reasons suggest themselves immediately for this meagerness. First, an actual large variation of density of the stream, even near the points of main condensation, one of which, it will be remembered, was the source of the display in 1833 and is not due to arrive at the earth's orbit until May, 1900. Secondly, the possibility of planetary perturbations since 1766, when the earth last encountered the part of the stream due this November, having materially diverted this part from a close approach to the earth's orbit. This is quite within reasonable probability, as, according to Messrs. Stoney and Downing, the perturbations of the orbit of the Leonids seen in 1866 have brought its intersection with the ecliptic over 1,000,000 miles inside the earth's path; and it is doubtful whether the stream possesses as great a thickness as that.

At New Haven the nights of Nov. 13–14 and 16–17 were perfectly clear, that of Nov. 15–16 mostly so after 1 A. M., Nov. 14–15 completely overcast throughout. Watch was kept at the Yale Observatory during this period and continuous photographs secured. But in all only 7 meteors of any brightness, 6 of them Leonids, were recorded as falling in the camera fields and none of them were bright enough apparently to impress themselves on the plates. W. L. E.

2. *National Academy of Sciences.*—The following is a list of the papers accepted for reading at the meeting of the National Academy held in New York on Nov. 14, 15.

OGDEN N. ROOD: Variations in normal color vision.

J. MCKEEN CATTELL: The time of perception as a measure of difference in intensity. Relations of time and space in vision.

THEODORE WILLIAM RICHARDS: The electro-chemical equivalents of copper and silver.

EDWARD C. PICKERING: Recent results of the Henry Draper Memorial.

R. S. WOODWARD: The statical properties of the atmosphere. A direct proof of the effect on the Eulerian Cycle of an inequality in the equatorial moments of inertia of the earth.

GEORGE F. BARKER: The hydrogen vacua of Dewar.

CHARLES S. PEIRCE: The definition of continuity. Topical geometry, in general. The map-coloring problem.

E. W. MORLEY: Memoir of W. A. Rogers as a physicist.

HENRY P. BOWDITCH: Report of the Delegates to the Wiesbaden Congress to consider the establishment of an International Scientific Association.

3. *The Races of Europe;* by WILLIAM Z. RIPLEY, Ph.D.; pp. 1-608 with a supplementary volume (159 pages) on the bibliography of the subject. New York, 1899 (Appleton & Co.).—These volumes are by a recognized leader in social science and constitute a sociological study, but will be equally welcomed by historians, anthropologists and geographers. Historians are recognizing the need of data regarding the physical make-up and traits of the peoples who have been and are now the actors on the historical stage. Anthropologists and geographers have long known that the fauna, flora, climate and geographical features have had a decided influence on the human species, but just how much and where these influences have been felt is a present point of discussion. It appears from the supplementary bibliography that there is a vast amount of raw material regarding races and physical environment. Much of it, however, is of uncertain quality and not easily accessible. Prof. Ripley has put us under obligations by collecting, weighing, interpreting and arranging this abundant original material and presenting it in an attractive manner. The amount of labor accomplished by the author and the saving in time for the reader will be appreciated by those who have done similar work. The European races with their colonial outgrowths form such complex groups, and their relationships and

geographical environment are so various, that all the inter-related social influences are involved when an effort is made to account for their condition. The author has wisely taken two of these forces, viz: race and physical environment—the only forces in social affairs which seem to rest on definable scientific foundations. The value and limitations of these two influences are traced throughout the book and the discussion of environment vs. race (Chapter XIX) is an attempt to explain the particular effect of each.

In the arrangement of the book the anthropological data—language, head form, color of hair and eyes, and stature—are first discussed, and groupings of the European people are made in accordance with these principles. Each race and type is then described in detail in a thorough, interesting manner. Students will be especially grateful for the clear presentation of the facts in regard to the little-known races of southeastern Europe and Asia Minor. The chapter on the Jews brings out their striking social solidarity and their equally striking response to environment. This chapter well deserves the attention it is receiving from scholars. Acclimatization (Chapter XXI) is of timely interest in that it treats of the possibility of adaptation of white races to tropical climates.

The illustrations are an important feature of the book. The portrait pages are serviceable in that they enable the reader to study the physical features of the race types almost at first hand. The numerous maps deserve commendation because they are made solely to illustrate the point in hand and not as an exhibition of artistic skill.

From the standpoint of the student—especially the English-speaking student—no more important contribution has been made to the broad field of social science than Ripley's Races of Europe.

H. E. G.

4. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1899 (W. Engelmann).—Recent additions to this valuable series of scientific classics are the following:

Nr. 104. Untersuchungen über die Chemischen Affinitäten. Abhandlungen aus den Jahren 1864, 1867, 1879. Von C. M. Guldberg und P. Waage. (182 pp.)

Nr. 105. Ueber das Geschlecht der Pflanzen. (De sexu plantarum epistola.) Von R. J. Camerarius. (1694.) (78 pp.)

Nr. 106. Abhandlung über Dynamik. Vou D'Alembert, de l'Académie Royale des Sciences (1743.) (210 pp.)

Nr. 107. Wahrscheinlichkeitsrechnung (Ars conjectandi). Von Jakob Bernoulli. (1713.) Erster und zweiter Theil. (162 pp.)

Nr. 108. Wahrscheinlichkeitsrechnung (Ars conjectandi). Von Jakob Bernoulli. (1713.) Dritter und vierter Theil mit dem Anhange: Brief an einen Freund über das Ballspiel (Jeu de Paume). (172 pp.)

OBITUARY.

SIR J. WILLIAM DAWSON. A telegram from Montreal, dated November 19, announces the death of the distinguished Canadian Geologist, Sir J. William Dawson, Principal of McGill University. A notice of Dr. Dawson is deferred until a later number.

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[*] This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto re mentioned.

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